BIOLOGY, POPULATION CHARACTERISTICS AND FISHERY OF THE RIDGE BACK SHRIMP, *SOLENOCERA CHOPRAI*, NATARAJ, 1945 ALONG SOUTH KARNATAKA COAST, INDIA.

Thesis submitted by

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For the degree of

Doctor of Philosophy in Biosciences

DEPARTMENT OF BIOSCIENCES
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Dedicated to
My beloved Parents

CERTIFICATE

This is to certify that the thesis entitled **"Biology, population characteristics and fishery of the ridge back shrimp, Solenocera choprai, Nataraj, 1945 along South Karnataka coast, India"** submitted by **Shri. A.P. Dineshbabu** for the award of Degree of Doctor of Philosophy in Biosciences is based on results of experiments carried out by him under my supervision at College of Fisheries, Mangalore. The thesis or part thereof has not previously been presented for any Diploma or Degree.

Mangalore
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DECLARATION

I do hereby declare that the thesis entitled ***"Biology, population characteristics and fishery of the ridge back shrimp, Solenocera choprai, Nataraj, 1945 along South Karnataka coast, India"*** *is the work carried out by me in the Department of Aquaculture, College of Fisheries, Mangalore, Dakshina Kannada, Karnataka, under the guidance of* ***Dr. Joseph. K, Manissery,*** *Professor, College of Fisheries, Mangalore. Further, I declare that the work has not previously been used as a basis for the award of any degree, diploma, fellowship or other similar titles.*

Mangalore
30-11-2005

A. P. Dineshbabu.

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A.P. Dineshbabu

Contents

Chapter 1

General Introduction

1. GENERAL INTRODUCTION

Crustaceans, comprising numerous edible species of shrimps, lobsters and crabs and inhabiting different ecosystems, form a significant portion of aquatic food resources of the world. India has ever remained one of the major contributors of marine crustaceans to the world production. Among crustaceans, shrimps are the most commercially exploited group and hold premier rank by virtue of its importance as an esteemed food of gourmet and on account of their high export value. As in the case of most countries of tropical region, the shrimp fishery of India is also of multi-species in nature. The common species supporting the shrimp fisheries of India belong to two major categories namely the "penaeid shrimps" and "caridean shrimps". The penaeid shrimps form the backbone of the seafood industry of the country as a major foreign exchange earner as well as a source of livelihood of millions of fish workers. Average annual penaeid shrimp catch in India during the period, 1999-2003 was 1,96,464 tonnes (t) contributing 7.7% to the total marine fish production (Pillai and Katiha, 2004). Frozen shrimps contributed about 70% (value at Rs. 4,480 crores) to the total export value of the country's marine products during 2002 and the share of capture fisheries was 59% by volume (Nandakumar and Maheswaradu, 2003).

Landing of shrimps in India showed a phenomenal growth in the last forty years with nearly seven fold increase from 32,000 t in 1960 to 2,07,080 t in 2000. This was achieved mainly by intense combing operation of inshore waters, introduction of night trawling and multi-day trawling and introduction of innovative gears in the artisanal sector (Nandakumar and Maheswaradu, 2003). In the early years of shrimp trawling, fishery was constituted by species belonging to the genera, *Parapenaeopsis, Metapenaeus* and *Penaeus.* The introduction of night trawling and multi-day trawling witnessed an emergence of some unconventional shrimp species like *Solenocera choprai, Trachypenaeus* spp., *Penaeus canaliculatus,* etc., in the landings. Along the northwest coast of India, *Solenocera* spp. emerged as one of the most dominant resources from 1993 onwards. During 1993-1999, *Solenocera* spp. constituted 27 to 34% of the shrimp landing along Gujarat coast. Along Maharashtra coast, *Solenocera* spp. emerged third in abundance after *Parpenaeopsis stylifera* and *Metapenaeus monoceros* (CMFRI Annual Reports, 1993 to 1999). Karnataka coast also witnessed the emergence of unconventional shrimp resources belonging to the genera, *Solenocera, Trachypenaeus, Parapenaeus* etc., in the landings from the year 1993 (Sukumaran *et al.*, 1998). *Solenocera* spp. landings of Karnataka coast was mainly constituted by a single species *Solenocera choprai* and their percentage contribution in the total penaeid shrimp landings during 1993-1997 was between 2.6% and 5.9%. During 1997-2002, the percentage of *S. choprai* along the coast increased steadily from 8% in 1997-1998 to 12% in 1998-1999 and further to 22% in 1999-2000. During 2000-2001, the contribution of the species in penaeid shrimp landings was 26%, which rose to 45% in 2001-2002.

Karnataka with a coastline of 300 km along the southwest coast of India is one of the frontline States of the country in marine fisheries development. The production rate (marine fish production/km coastline) of the State is almost double the national average right from the 1960s (Mohamed *et al.,* 1998). The principal gears used in the State are trawl net, purse-seine and gillnet in addition to a few small long-liners and a variety of artisanal gears. The trawl fleet in the State is distinctly of two types, a single-day fishing fleet (SDF) consisting of small (30-32 feet) coastal trawlers and the multi-day fishing fleet (MDF) consisting of larger (36-52 feet) trawlers operating in the 30-150 m depth zones (Zacharia *et al.,* 1996). The largest fleet in all the fishing harbours is the small coastal trawlers. Indigenous gears like '*matabale*', '*beenibale*', and '*jeppubale*' are operated mainly during the monsoon season but a few like '*kairampani*' and '*yendi*' are operated throughout the year. In 1986, the Government of Karnataka has passed the Marine Fisheries Regulation Act to regulate fishing activities and to de-limit fishing zones for different types of fishing vessels. Fishing by mechanised vessels is banned during the southwest monsoon months (June-August) along the entire Karnataka coast.

Mechanised gears accounted for more than 95% of the annual average catch in Karnataka. Of the mechanised gears, purse-seiners (44.8%) and trawlers (43.5%) together contribute 88.3% to the total catch. The last two decades have witnessed remarkable development in the mechanised fisheries sector. The trawl fishery has been intensified with the introduction of more number boats of varying sizes and horse-powers (HP), coupled with the extension of fishing grounds up to 150 m depth and beyond, and a change in the pattern of fishing, from single-day to multi-day fishing for shrimps and fishes for domestic use and export. The increased exploitation by the mechanised units has resulted in substantial increase in the catch of demersal finfishes and shellfishes. After the introduction of multi-day trawling, penaeid shrimp fishery of the State also improved substantially with increased shrimp landings as well as increased catch of new varieties of shrimps resulting in changes in the species composition. During 2000, some of the multi-day trawlers extended their operation up to 500 m by suitably modifying their units for such operations (Dineshbabu *et al.*, 2001).

There are 28 fish landing centres along Karnataka coast, of which Mangalore, Malpe and Karwar are the major ones. By reviewing the past ten year catch statistics from these centres, it was found that *S. choprai* formed a fishery only in two major trawl landing centres *viz.*, Mangalore and Malpe which are situated in the southern part of Karnataka coast. For the present study these two centres were selected for observation and collection of samples for biological and other related studies.

Mangalore ranks first in the total trawl landing as well as total shrimp landing in Karnataka. Mangalore and Malpe fisheries harbours together account for more than 40% of the shrimp landing in Karnataka. The penaeid shrimp catch along the coast is almost entirely contributed by trawlers except for some minor landings by 'ring seines" during monsoon and also occasional landing of coastal species by purse-seiners. Almost the entire shrimp fishery along this coast is supported by penaeid shrimps, except minor landing of *Acetes* spp. and landing of deep sea shrimps by deep sea trawlers.

During the present study the shrimp fishery for the period, 2003-2004 was analysed in detail. To understand the trend of shrimp fishery and the emergence of *S. choprai* fishery, the details of single-day and multi-day trawler units, hours of operation and catch details for the ten year period from 1993 to 2002 were also collected, an in-depth analysis of the data was done and the results are presented. As a non conventional resource, a thorough taxonomic study on the species was carried out during the present study as it would be useful to determine its exact systematic position.

For length measurements of shrimps and lobsters, various authors have used either total length or carapace length or both. For comparison of the data from different sources, the relationship existing between total length and carapace length is required and in the present study length-weight and other dimensional relationships of *S. choprai* were carried out.

Study of food and feeding and assimilation is of fundamental importance in understanding rate of growth, population concentration, gonad maturation and other metabolic activities. Further, knowledge on natural diet of an animal is required for the study of its nutritional requirements, its interaction with other organisms and its potential for culture (Williams, 1981). Information on food and feeding of *S. choprai* is of great importance since there are only a few similar studies attempted in India on the shrimp species occurring in the fishing ground beyond 50 m depths, especially those which are living in mid-shelf region. During the present study, food composition, feeding intensity and stomach fullness of adult males, adult females and juveniles during various months were studied in detail.

Since there are no reports available on the reproductive organs and reproductive biology of *S. choprai,* detailed studies on external reproductive characters and internal reproductive systems of male and female were attempted in the present study. Size at first maturity, maturity stages of females, fecundity, ova-diameter, breeding season and gonado-somatic index during various stages and seasons were also investigated in detail.

Growth studies form the basis for calculations leading to knowledge of mortality, recruitment and other fundamental parameters of the population. These parameters are the prerequisites for evolving effective management strategies for the judicious exploitation of the fishery resources. During the present study length-frequency data collected from Mangalore and Malpe fisheries harbours was used for determining the age and growth of *S. choprai*.

Studies on population dynamics of commercially important species are essential to help formulate fishing strategy to harvest the highest steady yield, year after year. In the light of the observations of ever growing importance of

S. choprai, it is essential to study the biology of the species, which is an essential prerequisite to formulate suitable management policies for rational utilisation of this resource.

Apart from basic studies conducted by Aravindakshan and Karbari (1994) on the fishery and biology of *S. choprai* from Bombay waters, studies on biology and the population characters of this species have not been attempted from any where in the world. In this context, detailed studies on the feeding, reproductive biology, growth and length-weight relationship of the species conducted in the present study is a pioneering attempt in this direction. The stock-size estimated from the study and the knowledge of the present exploitation rate will enable to formulate strategies for management and sustainable exploitation of this emerging resource.

The present work is documented and presented in four chapters, *viz.*, General Introduction, Review of Literature, Material and Methods and Results and Discussion. Details of fishery, taxonomy, length-weight relationship, food and feeding, reproduction, age and growth and stock assessment are presented as sub-divisions in these chapters except in General Introduction. The major findings of the study is summarised in the executive summary. Literature cited in full text, in abstract and translated forms are included in the reference section.

Chapter 2

Review of Literature

2. REVIEW OF LITERATURE

2.1. FISHERY

The wealth of information that was gathered on various aspects of fishery and biology of the commercially important species of shrimps along the Indian coast has been consolidated and documented in a series of species synopsis, published in the world scientific conferences on "The biology and culture of shrimps and prawns" held at Mexico in 1967 (Mistakidis, ed., 1968). Subsequent information on shrimp fisheries and biology of economically important shrimps are available from a number of contributions. Some of them are Kunju (1967), Jones (1969), Mohamed and Suseelan (1973), George (1974), Kurup and Rao (1974), Thomas (1974, 1975), Kurian and Sebastian (1976), Sukumaran (1978), Silas *et al.* (1984), Rao (1986), Deshmukh (1988), George *et al.* (1988), Suseelan *et al.* (1992), Suseelan and Rajan (1989), Aravindakshan and Karbari (1994) Nandakumar (2001) and Dineshbabu (2003, 2004, 2005).

Information on the shrimp resources of Karnataka coast is largely derived from the accounts given by the Department of Fisheries, Mysore (Anon., 1962, 1978), Nagabhushanam *et al.* (1964), Kuthalingam *et al.* (1966), Ramamurthy (1972) and Sukumaran (1982). Ramamurthy and Sukumaran (1984) analysed the penaeid shrimp fishery of the coast during 1970-1980. The effect of change in trawling pattern and its impact on the fishery along Mangalore coast were reported by Sukumaran (1985), Zacharia *et al.* (1996), Sukumaran *et al.* (1998), Mohamed *et al.* (1998) and Dineshbabu *et al.* (2001)

Kurien and Sebastian (1976) in the mid-seventies predicted that *Solenocera choprai* have got the potential of becoming a fishery in the future. Suseelan *et al.* (1982) reaffirmed this prediction based on their studies along Kerala coast. Aravindakshan and Karbari (1994) studied the potential of the fishery and conducted biological studies of the species during 1977-1986 from Bombay waters. Along Kerala coast, Nandakumar *et al.* (2001) while analysing the fishery of Sakthikulangara fisheries harbour for the period 1986-2000 reported that, average annual landing of *S. choprai* was 286 t, and the fishing season for the species was during October-November and February-May. Sukumaran *et al.* (1998) described the occurrence of *Solenocera* species in the shrimp landings of Karnataka coast for the first time. Dineshbabu *et al.* (2001) described the fishery importance of *S. choprai* and emergence of the species as the highest contributor to the shrimp fishery of Mangalore coast.

2.2. TAXONOMY AND DISTRIBUTION

Shrimps are generally distinguished into two catogories; penaeid shrimps and non-penaeid shrimps. The penaeid shrimps come under sub-order Dendrobranchiata, and are distinguished from other shrimps (Caridea) by their gill structure (Dall *et al.*, 1990). Solenoceridae comes under Dendrobranchiata, under super family Penaeoidae. Thus the shrimps of

Solenoceridae family are also referred as penaeid shrimps (as per their infraorder) and this terminology is used in the present text also. The penaeids are called as both shrimps and prawns, the usage varies with locality and both the usages have some historical precedence. To reduce the anomaly, FAO accepted the term "shrimps" for penaeids, which is generally harvested from marine and brackishwater environments and this term is used to describe *S. choprai* in the present text.

S. choprai is widely distributed in the Indo-Pacific along eastern coast of Africa , Madagascar, Gulfs of Suez and Arabia, Pakistan, India, Malaysia, Philippines, Indonesia, Taiwan, Thailand and northeast and northwest Australia. In Indian waters, Nataraj (1945) stated that the types and co-types of *Solenocera choprai* were collected by "R.M.I.S. *Investigator*" in the Arabian Sea (17° 27' N., 71° 41' E.) from a depth of 56 to 58 fathoms during 1898. Two males and two females were again collected by the same steamer in the Andaman sea during 1899. Following this report, there were records of stray occurrence of the species in different explorative surveys along both the coasts. Along northwest coast of India, *Solenocera crassicornis* was established as a regular fishery since long time and the presence of *S. choprai* in the landings was very rare and occasional. *S. crassicornis* was caught from a depth within 40 m and *S. choprai* from the ground beyond 50 m depth. Another species, *S. hextii* was reported as stray catches from a depth of 120 to 500 m off east and west coasts of India. George (1966), Mohamed (1973) and

Kurien and Sebastian (1976) collected and described altogether ten species of shrimps belonging to the genus *Solenocera* from Indian waters. The species collected were *S. pectinata*, (Bate), *S. koelbeli* de Man, *S. hextii* Wood-Mason & Alcock, 1891, *S. alticarinata* Kubo, 1949, *S. (Parasolenocera) annectens* (Wood-Mason, 1891), *S. indica* Nataraj, 1945, *S. choprai* Nataraj, 1945, *S. walterensis* George& Muthu, 1970, *S. melentho* deMan, 1907 and *S. subnuda* Kubo, 1949.

The taxonomic position of *Solenocera choprai* Nataraj, 1945 was described by various authors like George (1969), Starobogatov (1972), Tirmizi (1972), Crosnier (1978, 1984, 1989, 1994), Grey *et al.* (1983), De freitas (1985) and Kensley *et al.* (1987).

Distribution of *S. choprai* around the world was studied by various workers. From eastern coast of Africa *S. choprai* was recorded and described by De freitas (1985). Tirmizi (1972) recorded the species from Pakistan waters. From Indian waters this species was described first time by Nataraj (1945). Yu and Chan (1986) described the fishery of the species from Taiwan while, Crosnier (1989) reported the collection of specimens from Indonesia, Malaysia and Philippines. Dall (1999) described the distribution of *S. choprai* in Australian waters. Chan (1998) stated that *S. choprai* was found on soft bottoms at the depth between 50 and 175 m probably burrowing in the mud during daytime, with only tube-like antennular flagella sticking out for respiration.

2.3. LENGTH-WEIGHT RELATIONSHIP

Every animal in its life grows both in length and weight, the relationship between these two has both theoretical and practical importance. It has been mathematically proved that there is a fairly constant relationship between total length and weight of the individuals of the species. It helps to establish a direct mathematical relationship between the two variables, namely length and weight, so that if one is known the other could be easily computed. Length-weight relationship is also needed for studies on maturity and yield estimates by analytical models.

In Indian waters, various authors derived the length-weight relationship of various shrimps for the direct and indirect usages in the biology and stock assessment of the species (George, 1959; Rajyalakshmi, 1961; Rao, 1967; Thomas, 1975; Sukumaran and Rajan, 1981; Lalithadevi, 1987; Rao, 1988, and Nandakumar, 1997). Relationship between total length and carapace length of three commercial prawns were studied by Ramamurty and Manikkaraja (1978) from Mangalore coast. For comparison of the data from different sources, the relationship existing between total length and carapace length is required. Ivanov and Krylov (1980) conducted morphometric studies on shrimps belonging to *Penaeus, Metapenaeus, Penaeopsis Parapenaeus, Haliporoides* and *Aristaeomorpha* genera and formulated general procedure for morphometric studies in shrimps. Length–weight relationship of *Haliporiodes sibogae* belonging to Solenoceridae family was studied by Baelde (1994) from Australian waters. In most of these studies the relationships between carapace length and total length of shrimps were also worked out. There is no previous record on length-weight relationship studies on *S. choprai*. However, total length-carapace length relationships and length–weight relationships of *S. crassicornis* (*S. indica*) from Bombay waters were studied by Kunju (1968) and Sukumaran (1978) respectively. Length-weight relationship of *S. acuminata* caught off French Guiana coast was studied by Gueguen (1997). Length–weight relationship of *S. melantho* was studied by Ohtomi and Irieda (1997) from Kagoshima Bay of Japan.

2.4. FOOD AND FEEDING

As food being the most important factor regulating or influencing the abundance, growth and migration of shrimps, any information in this regard will add to the existing knowledge needed for better management of shrimp stock. Diet of a shrimp population is examined with a view to assess the nutritional standing of the species in a community. Study of seasonal variation in diet and dietary comparison between different sub-groups of the species like year-class will help to understand whether there is competition for food.

In general, penaeid shrimps have been described as "omnivorous scavengers" or "detritus feeders". Under natural conditions, in a densely populated shrimp ground, the proportion of larger food masses may not be adequate for full nutrition of the population. It has been assumed that this deficiency is made good by "detritus". Shrimps do not appear to be predators. But small sized, disabled or dying animals are readily attacked by starving shrimps (Dall, 1968). Kishinouye (1900), Ikematsu (1955), Kubo (1956) and Yasuda (1956) have studied feeding habit of shrimps and opined that most of the adult shrimps have carnivorous food habit. The shrimps feed by moving slowly and methodically searching the surface with the three pairs of chelipeds. The tips of each chela meet precisely, so that quite small particle may be picked up and conveyed to the mouth. When a relatively larger food mass was found, it is held by the external maxillipeds and the mandibles are used to bite or tear off portions. The maxillipeds are then used to push tough food away as it is grasped by mandibles.

Dall (1957) in his description of the digestive organs stated that there is only little difference in the overall structure of the stomach in the penaeid shrimps except in the details of the gastric mill. Detailed studies have been made on food and feeding habits of shrimps of Indian waters by various workers (Menon, 1951; Gopalakrishnan, 1952; Panikkar, 1952; Panikkar and Menon, 1956; George, 1959; Kunju, 1967; Subramanyam, 1967; Thomas, 1972; Kuttyamma, 1974; George, 1974; Mohanty, 1975; Subramanyam and Ganapathi, 1975; Thomas, 1980; Nandakumar, 1997 and Dineshbabu, 2004).

Since the quantity of food in the stomach of shrimps is very little the 'points method' is used for the stomach content analysis in the present study (Pillay, 1952 and Williams, 1981). Instead of volumetric method, in order to get a summary picture of frequency of occurrence as well as volume of various items 'Index of Preponderance' method (Natarajan and Jhingran, 1961) was used. This method was used by Nandakumar (1997) for the stomach content studies of *M. monoceros* along Kerala coast. Mc Laughlin and Hebard (1961), Newman and Pollock (1974), Caine (1975), Donaldson (1975), Hill (1976), Gotshall (1977), Keast (1978), Scarrat (1980) and Saint-Marie and Chabot (2002) studied the feeding habits in crustaceans using the percentage of occurrence of food types as the only measure of relative intake of different items. Ropes (1968) used percentage of occurrence and counts of number of certain prey to describe the natural diet in *Carcinus maenas*. Kennedy *et al.,* (1977) used predominant and residual classification of food types of stomach content of *Homarus americanus.* Hartnoll (1963) used points method which was scaled to take account of fullness of stomach. Williams (1981) evaluated the different methods of stomach content analysis and suggested that the points method, considering the fullness of stomach content as volume is more realistic in stomach content analysis.

Various authors incorporated study of feeding ecology in the food and feeding studies of shrimps (Williams, 1955; Eldred *et al.,* 1961; Hall, 1962 and Dall, 1968). While following a holistic ecosystem approach they could give satisfactory explanation for the variation of food and feeding habits of the shrimps during various seasons and also during different life stages. Tiews *et al.* (1968) and Marte (1980, 1982) through their studies on the feeding ecology of penaeid species explained how variation in the ecology influence the feeding habits of penaeid shrimps. Similar studies were conducted by Chong and Sasekumar (1981) in *P. merguiensis*, Cartes and Sardah (1989) in deep sea shrimp, *Aristaeus antinnatus* and Kapris (2004) in *Parapenaeopsis longirostris*. In the present study, ecological aspects such as bottom structure and upwelling are also incorporated while explaining the variation of stomach contents during different seasons.

Food and feeding habits of *S. choprai* were studied by Aravindakshan and Karbari (1994) from Bombay waters and found that the species have a carnivorous feeding habit, feeding preferably on decapods. Food and feeding habits of *S. indica* (*S. crassicornis*) were studied by Kunju (1968). While studying the biology of Indo-Pacific penaeid shrimps, Hall (1962) studied the food and feeding habits of *S. alticarinata* from Malaysian waters.

2.5. REPRODUCTION

An understanding of the reproductive biology of any given species is an essential prerequisite for stock assessment in wild populations and sustainable exploitation. Knowledge of the total number of eggs produced by a shrimp is important in determining the spawning potential of the shrimp. Different aspects on the reproductive biology of penaeid shrimps have been studied by a number of workers (Hudinaga, 1942; King, 1948; Eldred, 1958; Cummings, 1961; Oka and Shirhata, 1965; Tuma, 1967; Perez- Farfante, 1975; Penn, 1980, Yano, 1988 and Tan Fermin and Pudadera, 1989).

Wickins (1976) reviewed the results of studies carried out on reproduction and breeding of cultivable penaeid shrimps. In Indian waters important species studied were *Metapenaeus dobsoni* (Menon, 1951), *Parapenaeopsis stylifera* (Menon, 1953, Shaikhmahmud and Tembe, 1958) *Penaeus indicus* (Subramanyam, 1963), *Penaeus semisulcatus* (Thomas, 1974) and *Metapenaeus monoceros* (Rao, 1989, Nandakumar, 1997). Reproductive biology of commercially important penaeid shrimps of the southwest coast of India was compiled by Rao (1968, 1978). Dineshbabu (2004) described the reproductive biology of six commercially important penaeid shrimps from Saurashratra coast.

Penaeid shrimps have well developed secondary sexual structures for spermatophore implantation (petasma) and reception (thelycum). Spawning usually occurs in open waters (George and Rao, 1968). Maturity of males of penaeid shrimps was studied by Burukovskij (1980). Subramoniam (1993) gave a detailed account on the morphology, composition and transfer of spermatophores in penaeid shrimps. Fecundity of penaeid shrimps are generally higher than those of caridean shrimps, producing 50,000 to 1,30,000 small eggs (Dall *et al.*, 1990) in each spawning. The identification of maturity stages is important in finding out the spawning season of the shrimps. Werner (1972), Penn (1980), Anderson *et al.* (1984), King and Moffit (1984), Bell and Lightner (1988), Courtney and Dredge (1988) and Levi and Vaachi (1988) explained different methods for the identification of female maturity stages in penaeid shrimps. King (1986) while, studying the sex ratio of crustaceans found that in many of the crustaceans, male preponderance exists up to certain length classes and after that female preponderance becomes predominant. In tropical and subtropical countries, bimodal spawning and recruitment are common but seasonal rainfall and lower winter temperature often result in one or the other generation being dominant in the offshore phase (Garcia and Le Reste, 1981).

Apart from reports on incidence of matured females during September and fecundity estimates of *S. choprai* from Bombay waters (Aravindakshan and Karbari, 1994), there is no reported work on the reproductive biology of the species. Kunju (1968) and Sukumaran (1978) studied the reproductive biology of *S. crassicornis* from Bombay waters. Dineshbabu (2003) studied the reproductive biology and spawning season of *S. crassicornis* from Saurashtra waters. There were only few reports on the study of reproductive biology of shrimps belonging to *Solenocera* genus, and the species studied were, *S. prominestis* (Chalayondeja and Tanoue, 1971), *S. acuminata* (Gueguen, 1998), *S. melantho* (Ohtomi *et al.,* 1998), *S. alticarinata* and *S. melentho* (Kao *et al.,* 2001). Baelde (1992) gave a detailed report on the reproductive biology of shrimps *Haliporoides sibogae*, belonging to Solenoceridae family.

2.6. AGE AND GROWTH

Growth can be expressed as an increase in length, volume or weight with time (Hartnoll, 1982). The size attained by a crustacean at any age is determined by the number of moults and increase in size at each moult. In practice, owing to difficulty in incorporating such phenomena in mathematical models, growth is considered essentially as a continuous process and measured as size at time or size at age directly. Penaeid shrimps appear to conform to the typical growth pattern of a sigmoidal growth form as in fishes (Dall *et al.*, 1990). There are several methods available to determine the age and growth of shrimps such as tagging (release and recapture methods), culturing the shrimps in cages and ponds and studying their growth in captivity and analysing the length- frequency of the population. The first two methods offer direct evidence, but these methods require lot of expenditure and technical know-how. The direct methods of tagging and marking for studying the growth are unreliable operations in crustaceans owing to their discontinuous growth and occurrence of moulting (Garcia and Le Reste, 1981). Crustaceans do not have a bony structure which records an imprint of internal or environmental variations which would allow age to be read directly. Yano and Kobayashi (1969) stated that the number of lamellae in the endocuticle increases with size and thus may give some possibility of age determination. Sheehy (1989, 1990, 1992) reported that quantification of lipofuscin accumulation by image analysis has significant potential as means of age determination for crustaceans.

The method of analysing length-frequency distribution has found wider application in the tropics. It was first introduced by Petersen (1900) in which peaks in the length-frequency of a given sample are assumed to represent different year classes or age groups. The main shortcoming in this technique is that the modes representing the older shrimps may overlap as the growth rate slows down considerably with increasing age and thus making the fixation of age difficult. However, separation of the year classes was made possible by graphical methods (Harding, 1949; Cassie, 1954; Bhattacharya, 1967) or computer based methods (Hasselblad, 1966; Yong and Skillman, 1971).

Electronic Length Frequency Analysis (ELEFAN), a computer based method for length-frequency data analysis was introduced as a rapid, reliable method to split the composite length-frequency into peaks and troughs and the best growth curve passing through maximum number of peaks is selected using a goodness of fit ratio of ESP/ASP (R_n) (Pauly and David, 1981, Gayanilo *et al.,* 1988). The peaks are assumed to represent individual cohorts. This routine has been incorporated into the FiSAT (FAO-ICLARM Fish Stock Assessment Tools) software (Gayanilo and Pauly, 1997). As it is user friendly, this software has wider acceptance in studies in crustacean growth over some of the mathematical models derived by Fournier *et al.* (1991) and Zeng and Wan (2000).

The age and growth of shrimps belonging to Solenoceridae family have been described by various authors. The important species studied were *S. crassicornis* (Cheung, 1963), *S. membranacea* (Heegard, 1967) and *S. promoinestis* (Chalayondeja and Tanoue, 1971). Baelde (1994) used MULTIFAN method (Fournier *et al.*, 1991) for studying the growth in deep-water royal shrimp, *Haliporoides sibogae* (Family: Solenoceridae) off Australian waters. Growth of the red shrimp *Aristomorpha foliacea* in Mediterranian sea was studied by Ragonese *et al.* (1994) using procedure of NONLIN of SYSTAT (Wilkinson, 1988).

The studies on age and growth of penaeid shrimps in India are mainly based on length- frequency method. Out of this many workers used "modal progression analysis by connecting the modes of length-frequency by smooth lines on graph paper (Menon 1953; Rajyalakshmi, 1961; George *et al.*, 1963, 1988; Banerji and George, 1967; Ramamurthy, 1967, 1980; Kurup and Rao, 1974; Thomas, 1975; Ramamurthy *et al.*, 1975, 1978; Lalithadevi, 1986, 1987 and Sarada, 2002) whereas others used computer aided LFSA and ELEFAN routine for the estimation of growth in penaeid shrimps (Suseelan and Rajan, 1989; Rao and Krishnamoorthi, 1990; Nandakumar and Srinath, 1999 and Dineshbabu, 2005).

From the Indian waters, growth studies on *S. crassicornis* were carried out by Sukumaran (1978) and Deshmukh (1988) from Maharashtra waters and Gujarat waters respectively. Since *S. choprai* is a new entry to Indian fishery no literature is available on the age and growth of this species.

2.7. STOCK ASSESSMENT

Aquatic living resources are limited and renewable. Among all the natural renewable resources, fisheries perhaps present the greatest challenge for effective management (Allsop, 1982). The dynamics of fish population are concerned with birth, growth and mortality of the stocks and these processes are governed by their adaptation to environment and reaction to fishing. Fishing, not only reduces the population, but also interferes with the adaptive relation of the fish species to its environment.

Mortality estimates form the basis for the stock estimation. Most of the earlier attempts to calculate mortality rates in shrimps were based on tagging experiments (Lindner and Andrson, 1956; Klima, 1964; Kutkunn, 1966; Costello and Allen, 1968). Neal (1968), Berry (1970), Garcia (1977), Jones and van Zalinge (1981), Cheng (1984), Pauly (1982), Pauly *et al.* (1984) and Ragonese *et al.* (1994) used length-frequency and catch composition to estimate mortality rates and presently this method is commonly used since it costs less and requires less facilities compared to tagging experiments.

Biological management of fishery resources involves proper assessment of their stocks. Stock assessment of fishery resources may be described as the search for the exploitation level, which gives the maximum yield in weight (Sparre and Venema, 1992). Mathews (1981) estimated the stocks of *P. stylirostris, P. californiensis, P. vannamei, P. setiferus and P. aztecus* in Mexican waters and prepared a comparative account of the results of various stock estimation studies on these species. Stock studies and population dynamics of deep water shrimps *Aristeus antinnatus* were carried out by Cartes and Demestre (2003) at Catalano-Balearic basin of Western Mediterranean. Stock assessment of deep water shrimp, *Haliporoides sibogae* (Family: Solenoceridae) along Australian coast was conducted by Baelde (1991) using commercial catch and effort data. Baelde (1994) did further studies on growth, mortality and stock assessment of *H. sibogae* in Australian waters using MUTIFAN method.

In the Indian waters mortality and stock assessment studies of shrimps were carried out by various workers (Banerji and George, 1967; Kurup and Rao, 1974; Ramamurthy, 1980; Lalithadevi, 1986, 1987; Rao 1988a, 1994; and Rao *et al.* 1993). Silas *et al.* (1984) and Rao (1988a) used surplus yield model to assess the stocks of shrimps. Along the Mangalore coast, stocks of *M. dobsoni* (Ramamurthy *et al.* 1978) and *P. stylifera* (Ramamurthy, 1980) were estimated. Stock assessment of these species along the entire Karnataka coast was carried out by George *et al.* (1988). Similar studies were conducted along Kerala coast also (Alagaraja *et al.,* 1986; Suseelan and Rajan, 1989; Nandakumar, 1997). Stock of *S.*

crassicornis was estimated from Bombay waters (Sukumaran, 1978) and from Gujarat waters (Deshmukh, 1988). Sukumaran (1978) used only catch and CPUE for the estimation of sustainable yield, whereas, Deshmukh (1988) incorporated growth parameters and mortality parameters in the stock assessment studies.

Two types of models have been developed to determine the quantitative effects of fishing on the stocks and to maintain and get optimum yield. The surplus production model or logistic model is a holistic model proposed by Hjort *et al.* (1933) and later developed by Graham (1939, 1943) and improved by Schaefer (1954). The analytical models were developed from the works of Baranov (1918), Thompson and Bell (1934), Ricker (1948) and Beverton and Holt (1957). These models consider biological parameters of populations (age, growth, mortality, etc.) and provide the yield information obtained from a unit number or weight of recruits under a series of varying fishing conditions. These models are also used for estimation of stock and for predicting future yields of a fishery.

Thompson and Bell model analyses the effect of fishing on a particular year class or cohort (virtual population analysis or cohort analysis) and based on the findings, the effect of fishing on the stocks in the future can be predicted. The second model, the yield per recruit model of Beverton and Holt (1957), assumes a steady state situation describing the state of stock and yield when the fishing pattern remains the same over a long period of time, so that all recruits are exposed to fishing. Ye (2000) effectively used the outputs from the yield per recruit model to suggest management measures for tropical shrimps and also to predict the fishery. The impact of closed seasons on the shrimp stock and fishery is also demonstrated with the help of these models (Ye, 1998).

Chapter 3

Material and Methods

3. MATERIAL AND METHODS

Data required for the study were collected twice a week from the commercial catches of Mangalore and Malpe fisheries harbours (Fig. 1.1) during 2003 and 2004. Trawling operations from these harbours were carried out from January to June and further from August to December during these years. From the second week of June to last week of August the trawling operations were stopped due to the monsoon ban imposed by State Government. Fishing operation details were collected from the commercial trawlers operating from these harbours. To describe bottom characteristics of the fishing ground, information collected by "FORV Sagar Sampada" was also used.

3.1. FISHERY

Observation of the fishery and analysis of data for the past ten years have confirmed that *S. choprai* landing in Karnataka is restricted only to Mangalore and Malpe fisheries harbours. Data on shrimp catch and effort were collected on an average of 8 days (2 days a week) in a calendar month. On each observation day, catch and effort data were collected at random from approximately 10 % of the fishing units landed at that centre.

Two categories of mechanised trawlers, *viz.,* single-day fishing fleet (SDF) and multi-day fishing fleet (MDF) are in operation in these two selected centres. The first category consists of small boats (<9.75 m OAL) making daily trips and fishing up to a depth of 30 m and an average of 5 hours of trawling was taken as the effort in fishing hours. The second category comprising medium sized boats (9.75-15.0 m OAL), carryout multi-day fishing at depths beyond 30 m. The number of days of absence of the observed boat from the landing centre was ascertained by enquiry and the catch details were noted at the landing centre by eye estimation. The multi-day boats were grouped in terms of number of nights spent in fishing, like one night fishing, 2 nights fishing, 3 nights fishing etc. for facilitating the estimation of effort in actual fishing hours. On an average, 6.6 hours were spent on actual fishing, out of each 12 hours of absence from the harbour by these units. There are trawlers operating for 7 nights at a stretch. Accordingly, the effort in actual fishing hours for 1 night, 2 nights (2 nights + 1day), 3 nights (3 nights + 2 days) and 4 nights (4 nights + 3 days) were 6.6 hours (6.6 hour x 1), 19.8 hours (6.6 hour x 3), 33 hours (6.6 hours x 5) and 46.2 hours (6.6 hours x 7) respectively. The number of units landed under each category was recorded on the observation days.

The mean catch and effort for the observed units under different categories on each observation day were raised to the total units of the respective type landed on that day to get the estimate for the day. Pooling the estimates for different observation days and raising to the total number of fishing days in that month gave catch and effort data for the month. Monthly estimates of catch and effort of shrimps landed were made based on the method described by Alagaraja (1984). The details regarding the area of fishing, depth of fishing, time of fishing, details of net and GPS readings of *S. choprai* fishing area were collected from commercial trawlers, "Sindhudaya" and "Sindhuja".

3.2. TAXONOMY

A total number of 100 males (55 to 90 mm) and 150 females (65 to 110 mm.) were examined for systematic studies following the methodologies described by Dall (1999).

3.3. LENGTH-WEIGHT RELATIONSHIP

Samples were washed thoroughly and excess water from the body removed using a blotting paper. After sexwise sorting, the total length, carapace length and total weight were recorded. To minimize the deviation in values due to weight increase during maturation process of females, females with fully matured ovary were excluded form the study (Ivanov and Krylov, 1980). The total length was measured from tip of the rostrum to the tip of the telson, to the nearest millimeter, keeping the abdomen fully stretched. Carapace length was measured from orbital notch to the posterior margin of the carapace along the mid-dorsal line by using vernier calipers. The individual weight was recorded to an accuracy of 0.01 g using an electronic balance (AFCOSET-FX-320).

To determine length-weight relationship, linear equation ($\log W = \log a + b \log L$) was fitted for males, females and sex pooled separately with the log transformed values of length and weight. Regression analysis was performed to determine the constants *a* and *b* and relationship between length and weight. The correlation coefficient (r) was determined to know the strength and pattern of association between the two variables. Similarly the relationship between total length and carapace length was also regressed.

Linear relationship as $Y = a + bX$ suggested by Ivanov and Krylov (1980) was used for the carapace length- total length relationship.

Analysis of covariance (Snedecor and Cochran, 1967) technique was used to test for any significant difference in the relationship in the above parameters between the sexes at 1% level. The 'Student's *t* test' was carried out to find out whether the *b* values for males, females and sex pooled were significantly different from 3 using the formula.

$$t = \frac{b - \beta}{S_b}$$ where β is equal to 3.

3.4. FOOD AND FEEDING

Samples of *S. choprai* collected during 2003 were analysed to study the food and feeding habits of the species. Due to the nibbling action of mandibles on the food and mastication of food inside the stomach by the action of gastric mill, identification of the food organisms was based mainly on broken shell remains, spines, setae etc. The stomach contents were grouped as follows: decapod crustaceans (mostly shrimps), fishes, molluscs, polychaetes, crustaceans other than decapods, foraminiferans, sand, detritus and unidentifiable digested matter (decomposed plant and animal matter and their remains mixed with mud) (Gosner, 1978). Since the quantity of food in the stomach of shrimps were very little, the 'points method' (Pillay, 1952 and Williams, 1981) was used in the present study. In order to get a summary picture of frequency of occurrence as well as volume of various items, 'Index of Preponderance' method (Natarajan and Jhingran, 1961) was used.

The index of preponderance was worked out by the following formula:

$$I = \frac{V_i O_i}{\Sigma V_i O_i} \times 100$$

Where V_i and O_i represent the percentage of volume and percentage of occurrence indices of each food item respectively and I, the index.

Stomach contents of 348 males, 351 females and 100 juveniles, were analysed. The intensity of feeding was determined by the degree of distension of the stomach due to the quantity of food inside the anterior and posterior chambers of the proventriculus. The condition of feeding was expressed as full, ¾ full, ½ full, ¼ full, trace and empty and each one was assigned, 100, 75, 50, 25, 10 and 0 points respectively. The stomachs were cut open and the contents examined under a microscope. The indices of preponderance were then computed to indicate the food preference of the species. The index of preponderance for the year was also calculated taking the total number of samples examined during the year. The degree of fullness of stomach in relation to size of the animal was noted to study the intensity of feeding in juveniles and adults. Form the total number of specimens examined in the month the percentage occurrence of stomachs with different intensities of feeding was computed. Food analysis was done in relation to months, sex, maturity stages and size-groups. The samples were classified into groups with a class interval of 5 mm total length. The stages were classified as 'immature', 'early maturing', 'late maturing', 'mature' and 'spent' (Dall *et al.*, 1990).

Test of analysis of variance (ANOVA) of food components and feeding conditions between males and females, between juveniles and adults, between months and between maturity stages of females were conducted with the help of SPSS statistical software (version 7.0).

3.5. REPRODUCTION

For the study of reproductive biology, total length and weight of males and females were recorded. After recording length and weight, ovaries from females were dissected out carefully. The colour and size of the ovary were recorded before preserving them in 5% formalin. The maturity stages could be differentiated from fresh specimens based on the colour and thickness of ovary (Dall *et al.*, 1990). However, the different maturity stages were confirmed later by microscopic examination. For ova-diameter studies, small portions of ovary (approximately 10 mg) taken from anterior, middle and posterior parts of the ovary were teased out on a glass slide and 300 ova from each portion were examined under microscope. As the diameter of ova collected from different regions of ovary did not indicate any variation, further studies on fecundity and ova- diameter were carried out using a portion of ovary on the right side of first abdominal segment. The diameter of ova was measured using an ocular micrometer, where one division equals 0.0150 mm. The ova were irregular in shape and measurement of each ovum was taken in the same parallel plane using mechanical stage of the microscope in order to avoid errors due to distortion and subjective bias.

The size at first maturity was found out by plotting the percentage of immature males and females against the matured ones with respect to the total length of the shrimp (Rao, 1989). For the size at first maturity (50%) studies in females, the specimens with early maturing ovary was rated as immature and females having late maturing, mature and spent ovaries were considered as matured ones. Shrimps with well-formed petasma and with presence of spermatophores in the terminal ampoule were taken as matured males (Baelde, 1992).

Preserved ovary after four or five days was washed and dried by placing it between two blotting papers. The weight of ovary was recorded and a sub-sample of ovary segment was taken out and weighed to the nearest 0.001g, using an electronic balance. The mature ova present in the sub-sample were counted by using a counting slide. From the number of ova in the weighed sub-sample, fecundity was calculated using the formula,

$$\text{Fecundity} = \frac{\text{total weight of the ovary}}{\text{weight of the sample}} \times \text{number of ova in the sample}$$

The relationship of fecundity on total length, total weight and ovary weight was found out by fitting regression on logarithms of observed values by least square method (Snedecor and Cochran, 1967).

$$F = aX^b$$

where,

F = Fecundity, a = constant, X = variable (total length, body weight or ovary weight) and b = correlation coefficient. The exponential relationship was transformed into a straight line logarithmic form based on the equation:

$$\log F = \log a + b \log X$$

For gonado-somatic index (GSI) estimation, females were weighed individually after wiping it dry. The gonad was dissected out carefully and weighed by using an electronic balance. The GSI was calculated by the methods described by June (1953) using the formula:

$$\text{GSI} = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100$$

GSI values for different maturity stages were calculated. In addition, monthly variations of GSI values were also calculated to study the relationship between the spawning season and GSI value. Before making assumptions based on GSI, the index was regressed against the total length of the specimen (after log transformation) to ensure that GSI is independent of the body size (West, 1990).

The sex ratio of *S. choprai* was studied based on the monthly estimated numbers during 2003 and 2004 so as to get an actual representation of males and females in the population. Homogeneity of the sex ratio (based on observed numbers) over months in two years has been tested using χ^2 test (Snedecor and Cochran, 1967).

The χ^2 is computed as follows:

$$\chi^2 = \frac{\sum(O-E)^2}{E}$$

where,

O = observed number of males and females.

E = expected number of males and females.

Significance test at a probability level of 'p = 0.01' was carried out. Homogeneity was tested for 1:1 ratio.

3.6. AGE AND GROWTH

Age and growth of *S. choprai* were estimated based on the length-frequency distribution data collected during the period of study. For getting the sex-wise length-frequency data, specimens were brought to the laboratory on each day of observation, sexed and length and weight measurements were recorded. The length-frequency data were grouped into 5 mm class intervals (e.g. 46-50, 51-55, 56-60 etc. with mid-points at 48, 53 and 58 respectively). The length-frequency distribution in the sample was raised to the total catch on the sampling day based on the sample weights. The data thus obtained for different sampling in a month were pooled to get catch in numbers for all the sampling days which in turn, were raised to the monthly catch. Growth was estimated separately for males and females. The length-frequency from the Mangalore and Malpe fisheries harbours were pooled and used for further analysis. The basis of the growth study is the growth equation formulated by von Bertalanffy (1934).

3.6.1. Growth equation

von Bertalanffy (1934) developed a mathematical model (von Bertalanffy Growth Formula-VBGF) for individual growth which has been shown to conform to the observed growth of most of the fishery resources. The VBGF equation is based on the concept of growth as a net result of the interaction of two opposite processes such as those tending to increase the mass (anabolism), and those tending to decrease it (catabolism), thus giving the growth curve fitting well with the growth rates of many species of organisms (Beverton, 1954; Beverton and Holt, 1957). Penaeid shrimps also appear to conform with the typical growth pattern of a sigmoidal growth form as in other fishes (Dall *et al.*, 1990). This mathematical model expresses the length, L as a function of the age of the fish or shrimp, t.

$$L_t = L_\infty \left[1 - e^{-K(t-t_0)}\right]$$

where,

L_t = length at age t

L_∞ = asymptotic length, or the maximum length that the fish or shrimp can theoretically attain

e = base of the Naperian or natural log,

K = curvature parameter (other-wise known as coefficient of catabolism or growth coefficient), the rate at which the fish or shrimp approaches asymptotic length,

t = age of fish or shrimp,

t_0 = age at which length of fish or shrimp is theoretically zero.

3.6.2. Growth parameters

The length-frequency data were analysed using the ELEFAN I module of FiSAT software (Gayanilo and Pauly, 1997) without prior decomposition of data and also through modal progression analysis after decomposition of multi-cohort samples into their component distributions.

The step-wise details of the analysis are given below:

1. Estimate of L_∞ and Z/K were made using the Powell-Wetherall method (Wetherall, 1986; Pauly, 1986)
2. The growth parameters were estimated using the ELEFAN I programme in the FiSAT software by identifying the best fit to the peaks.
3. L_∞ and K were used as input to the catch curve analysis.
4. The resultant catch curve was estimated following the procedure recommended by Pauly (1986). This routine smoothens a set of probability of capture over different length classes so that a resultant length curve is established and the mean size at first capture is derived.

5. The length-frequency is corrected using the probability of capture and a new set of length-frequency data was obtained.
6. Using the new (corrected) length-frequency data, procedure 2 was repeated and a new set of growth parameters were estimated.
7. From the corrected length-frequency data, composite distribution were decomposed into their components (Bhattacharya, 1967). Identification and linking of means (perceived to) belonging to the same cohorts were also carried out.
8. Using growth increments data resulting from the linking of means, growth parameters were estimated (Gulland and Holt, 1959).
9. The best fit of growth parameters were selected as representing growth of the species.
10. Using the growth parameters, the recruitment pattern was obtained by projecting the length-frequency data backward on to a one-year axis.

In the present study, a preliminary estimate of L_∞ was made using the Powell-Wetherall plot. Based on this, the automatic search routine, response surface analysis and scan of K values provided in the ELEFAN submenus of FiSAT were run to get the best fit of L_∞ and K. Using this as the input, the data were corrected for selection as the trawl gear allows the smaller shrimps to escape affecting the growth parameter estimates (Pauly, 1986). The data were corrected using the selection factors (L_{-50} and L_{-75}) obtained from the catch curve. The growth parameters were re-estimated using the data corrected for selection.

The monthly recruitment value pertains to months of the year when a precise estimate of t_o is available. t_o is also required for the calculation of growth in length using VBG equation. t_o was calculated by two methods; *viz.*, by using Gulland's formula (Gulland, 1969) with values of length obtained for different age in months as inputs and by Pauly's empirical equation (Pauly, 1979),

$$Log(-t_0) = -0.392 - 0.275 \log L_\infty - 1.038K$$

3.6.3. Comparison of growth parameters

The growth parameters were tested for their reliability by comparing them with the available growth studies of the same species or with related species in the same family. Since growth is not linear, growth comparisons in two populations using L_∞ and K separately may be misleading (Pauly, 1979). Longhurst and Pauly (1987) suggested an empirically derived growth performance index (phi prime index, Φ') which is expressed by the equation:

$$\Phi' = \log_{10} K + 2\log_{10} L_\infty$$

Dall *et al.* (1990) modified the method for using the same in shrimps and lobsters in which K was expressed in weekly basis and L_∞ was expressed as carapace length (mm) and this method was used for the present study.

3.7. STOCK ASSESSMENT

For the purpose of stock assessment studies, *S. choprai* landed by the multi-day trawlers at Mangalore and Malpe fisheries harbours were sampled for length-composition data. The monthly length-composition data from these harbours were pooled and used for the estimation of stock parameters and further for stock assessment of the species. Monthly length composition data collected from these harbours, were pooled and used for further analysis. The effort expended by the multi-day trawlers during 2003-2004 was considered as the fishing effort for the study. The other necessary inputs for stock analysis were the estimates of growth parameters, L_{∞}, K and t_0 obtained from the 'age and growth' studies of the species.

The mortality in shrimps is due to natural causes and fishing which is expressed as total mortality coefficient or instantaneous rate of total mortality and denoted by Z. Natural mortality due to predation including cannibalism and other factors such as disease, parasitic infections, starvation, old age and environmental conditions acting independently is expressed as instantaneous rate of natural mortality M. Fishing mortality caused by fishing activity is expressed as instantaneous rate of fishing mortality F.

3.7.1. Total mortality coefficient (*Z*)

The total mortality coefficient (Z) was estimated from the length-frequency data for the years 2003 and 2004 as well as pooled data by using length-converted catch curve method of Pauly (1983) and the cumulative catch curve method of Jones and van Zalinge (1981).

3.7. 2. Natural mortality coefficient (*M*)

The natural mortality coefficient of *S. choprai* was calculated by the methods of Sekharan (1974), Rikhter and Efanov (1976), Pauly (1980) and Srinath (1990).

3.7.2.1. Sekharan's method (Sekharan, 1974)

Under this method, M was estimated assuming that 99 % of shrimp by number would die if there was no exploitation by the time they attain t_{max} which corresponds to L_{max} in the catch, where L_{max} is the maximum observed length in catch and t_{max} is the corresponding age of the shrimp calculated from VBGF equation.

$$M = \frac{1}{t_{max}} \times \log e \frac{100}{1}$$

3.7.2.2. Rikhter and Efanov method (Rikhter and Efanov, 1976)

This method employs the following formula:

$$M = \frac{1.521}{t_m^{0.72}} - 0.155$$

where, t_m = age at which 50 % of the population matures.

3.7. 2. 3. Pauly's method (Pauly, 1980)

M was also derived using the following empirical formula of Pauly (1980),

$$\log_{10} M = 0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where, L_{∞} is expressed in cm, and T is the mean annual sea water temperature (26°C is taken as T in the present study based on the results of the observations made from 'FORV Sagar Sampada' at a depth range of 50 to 100 m).

3.7.2. 4. Srinath's method (Srinath, 1990)

Srinath proposed the following empirical formula to estimate natural mortality

$$M = 0.4603 + 1.4573\ K$$

where 'K' is the growth coefficient.

3.7. 3. Probabilities of capture

The probability of capture by length (Pauly, 1983a) of S. *choprai* was calculated by the ratio between the points of the extrapolated descending arm of the length-converted catch curve using the FiSAT software.

3.7. 4. Fishing mortality coefficient (*F*)

The instantaneous fishing mortality coefficient (F) was computed from the following relationship:

$$F = Z - M$$

3.7. 5. Exploitation rate (*U*)

This is defined as the fraction of shrimp present at the start of a year that is caught during the year (Ricker, 1945). This is estimated by the equation given by Beverton and Holt (1957) and Ricker (1945) as-

$$U = \frac{F}{Z}\left(1 - e^{-Z}\right)$$

3.7. 6. Exploitation ratio (*E*)

This refers to the ratio between fish caught and the total mortality (Ricker, 1945) or the exploitation rate or the fraction of deaths caused by fishing (Sparre and Venema, 1992). It is estimated by the equation-

$$E = \frac{F}{Z} = \frac{F}{M + F}$$

The *E* gives an indication of the state of exploitation of a stock under the assumption that the optimal value of exploitation is 0.5 or $E \approx 0.5$ which in turn is based on the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

3.7.7. Yield (*Y*)

Yield is the fraction of shrimp population by weight taken by the fishery and is denoted by *Y*.

3.7. 8. Standing stock (*Y/F*)

This term refers to a concentration of shrimp population for a given area at a given time. It is measured in terms of numbers or weight and is estimated from the relation *Y/F*.

3.7. 9. Total stock or annual stock or biomass (*Y/U*)

This refers to the total weight or number of shrimp population available for a given area at a particular time. It is estimated from the relation Y/U where Y is the yield and U is the exploitation rate.

3.7.10. Maximum sustainable yield (*MSY*)

This refers to the weight of shrimp that can be taken by fishing without reducing the stock's biomass on a continuing basis. The MSY was calculated by the formula of Gulland (1965) as-

$MSY = Z(Y/F)*0.5.$

The MSY was also calculated from the length-based Thompson and Bell model as given under section 3.7.12.

3.7.11. Virtual population analysis -VPA (Gulland, 1965)

The term virtual population means the part, by number, of a shrimp stock that is alive at a given time and which will be caught in future. In Virtual Population Analysis (also known as Cohort Analysis), the annual catch obtained from a single cohort during the exploited phase is used to calculate the abundance and fishing mortality rates of the cohort in each year. Managing a fishery by limiting effort requires estimates of annual abundance and total catch at different levels of fishing effort. VPA is a suitable method in such situations.

The basic equations used in this analysis are:

1. $C(i,t,t+1) = N(i,t)\dfrac{F(i,t,t+1)}{M+F(i,t,t+1)}\exp[M+F(i,t,t+1)]$

2. $\dfrac{C(i,t,t+1)}{N(i+1,t+1)} = \dfrac{F(i,t,t+1)}{M+F(i,t,t+1)}\{\exp[M+F(i,t,t+1)]-1\}$

3. $N(i,t) = N(i+1,t+1)\exp[M+F(i,t,t+1)]$

(the notation *exp(x)* is used in place of e^x)

The terms used in these equations have the following meanings:

$C(i,t,t+1)$	:	Catch in number for year i with ages between t and $t+1$.
$N(i,t)$	:	Number of shrimp (survivors) of age t in the sea at the beginning of year i.
$F(i,t,t+1)$	:	Instantaneous rate of fishing mortality during the year i for those between ages t and $t+1$.
M	:	Instantaneous rate of natural mortality which is assumed to be the same for all age groups.
$Z(i,t,t+1) = M + F(i,t,t+1)$	:	Instantaneous rate of total mortality during the year i for those between ages t and $t+1$.

The calculations for VPA are started from the bottom (highest age class in the catch, also known as the terminal class). With an initial guess of the fishing mortality for the terminal class (terminal F value), knowing the estimate of natural mortality M and catch for the terminal class, we can estimate the number of survivors at the beginning of the year for this class from the first equation as:

$$N(i,t) = \frac{M+F(i,t,t+1)}{F(i,t,t+1)}\frac{C(i,t,t+1)}{\exp[M+F(i,t,t+1)]}$$

Since the number of survivors at the beginning of a year is same as the number of survivors at the end of the previous year, we can estimate the fishing mortality for the immediate previous age class from the second equation in which the only unknown factor will be $F(i,t,t+1)$. The number of survivors for this class can be estimated using the third equation. This procedure can be repeated in this fashion starting from the last age class to estimate fishing mortality and number of survivors for each of the age classes.

3.7.12. Length-based Thompson and Bell model

The Thompson and Bell model is the predictive version of VPA, which can predict the stock size and the catch for various assumptions on the future fishing pattern. The inputs are the same as that of the cohort analysis and the additional inputs required are the parameters of the length-weight relationship and the average value (Rs./kg) by length group. The outputs are the number in each lower limit of the length group *N (L1),* the catch in numbers, the yield in weight, the biomass multiplied by Δt, *i.*e. the time required to grow from the lower limit to the upper limit of the length group and the value. Finally, the totals of the catch, yield, mean biomass x Δt and value are obtained. The calculations are repeated for a range of *F* values and the final results are plotted in graphs.

The equation to calculate *F* in length-based VPA is rearranged as:

$$C(L_1, L_2) = [N(L_1) - N(L_2)] * \frac{F(L_1, L_2)}{Z(L_1, L_2)}$$

This gives the equation

$$N(L_1)=\left[N(L_2)*H(L_1,L_2)+\frac{N(L_1)-N(L_2)}{Z(L_1,L_2)}*F(L_1,L_2)\right]*H(L_1,L_2)$$

where

$$H(L_1,L_2)=\left[\frac{L_\infty-L_1}{L_\infty-L_2}\right]^{M/2K}$$

with respect to $N(L_2)$

$$N(L_2)=N(L_1)*\frac{1/H(L_1,L_2)-F(L_1,L_2)/Z(L_1,L_2)}{H(L_1,L_2)-F(L_1,L_2)/Z(L_1-L_2)}$$

the catch in numbers has to be multiplied by the mean weight of the length group,

$$\bar{w}(L_{1,}L_2)=q*[L_1+L_2/2]^b$$

where q and b are the parameters of the length-weight relationship a and b respectively. The yield is given by

$$Y(L_1,L_2)=C(L_1,L_2)*\bar{w}[L_1,L_2]$$

and value is given by

$$V(L_1,L_2)=Y(L_1,L_2)*\bar{v}(L_1,L_2)$$

where $\bar{v}(L_1,L_2)$ are the average value (Rs./ kg) of *S. choprai* between lengths L_1 and L_2. The number of survivors of the length group decreases when a cohort grows from L_1 to L_2 and is calculated as-

$$\bar{N}(L_1,L_2)*\Delta t(L_1,L_2)=[N(L_1)-N(L_2)]/Z(L_1,L_2)$$

and the corresponding mean biomass * Δ_t is

$$\bar{B}(L_1,L_2)*\Delta t(L_i,L_2)=[N(L_1)-N(L_2)]/Z(L_1,L_2)$$

The average biomass during the lifespan of a cohort or all cohorts during a year is given by $\overline{B} = \sum \overline{B_i} * \Delta t_i$

3.7. 13. The relative Y/R model (Y'/R)

Beverton and Holt (1964) based on the realisation that the absolute value of Y/R expressed for example in terms of grams per recruit per year, has no direct relation to fisheries management, proposed the relative yield per recruit based on the concept that what matters is the relative differences of Y/R for different values of *F*. The model requires fewer parameters and is especially suitable for assessing the effect of mesh size regulations.

$$\left(Y/R\right)' = E\, U^{M/K} \left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right]$$

where

$$m = \frac{1-E}{M/K} = \frac{K}{Z}$$

$$U = 1 - \frac{L_c}{L_\infty}$$

and

$E = \dfrac{F}{Z}$ is the exploitation rate which is the fraction of deaths due to fishing.

The relation between relative yield per recruit $\left(Y/R\right)'$ and the yield per recruit $\left(Y/R\right)$ is

$$\left(Y/R\right)' = \left(Y/R\right)\exp[-M(t_r - t_0)]/W_\infty$$

where t_r is the age at recruitment and t_0 is the age corresponding to zero length, which is a parameter in VBGF.

Knowing the relative yield per recruitment, the corresponding yield per recruitment can be calculated using the following equation.

$$\left(Y/R\right) = \left(Y/R\right)' W_\infty \exp[M(t_r - t_0)]$$

The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano, 1986).

The concept of $F_{0.1}$ in the (Y'/R) model is to limit F to the values which correspond to 1/10th rate of increase of yield per recruit that can be obtained by increasing F at low levels of F (Gayanilo and Pauly, 1997). $E_{0.1}$ is defined as the exploitation rate at which the marginal increase of relative yield per recruit is 1/10th of its value at E = 0.1. The yield per recruit was calculated as a function of mesh size or age at first capture and of fishing effort or fishing mortality through yield isopleth diagram.

Chapter 4

Results and Discussion

4.1. Fishery

4.1. FISHERY

4.1.1. RESULTS

4.1.1.1. Trawl fishery

During 2003, 62,012 trawl units were operated from Mangalore and Malpe fisheries harbours, out of which 55 % were single-day units and 45 % were multi-day units. However, when actual fishing hours are considered, single-day units expended 9% of the total actual fishing hours. For multi-day trawler, average hours of fishing operation per trip were 64 whereas, the same for single-day trawler was 5 hours per unit. The total landing from trawl fishery at Mangalore centre was 41,913 t, of which 38,433 t were landed by multi-day trawlers. At Malpe, the total trawl landing was 28,358 t and of which 24,942 t was contributed by multi-day trawlers. Details of trawl fishery at Mangalore and Malpe fisheries harbours during 2003 are given in Tables 1.1 to 1.4.

During 2004, 45,171 trawl units operated from Mangalore and Malpe fisheries harbours, of which 46% were single-day units, expending 5% of the total fishing hours. The total landing by the trawlers at Mangalore was 47,419 t, of which 44,889 t were contributed by multi-day trawlers. At Malpe, the total trawl landing was 19,087 t with multi-day trawlers contributing about 16,508 t. When compared to 2003, the total trawl landing increased at Mangalore whereas at Malpe the total landing showed a reduction. Details of trawl fishery at Mangalore and Malpe fisheries harbours during 2004 are given in Tables 1.5 to 1.8.

4.1.1.2. Shrimp fishery

During 2003, at Mangalore and Malpe fisheries harbours, 3,749 t of penaeid shrimps were landed by single-day and multi-day trawlers together, with a catch rate of 60.46 kg per unit (Table 1.9). The highest landing was observed in January with 603 t. The landings gradually decreased to 392 t by May. Similar trend was observed from September to December also and during this period the landings decreased gradually from 415t to 227 t.

During 2003, 12 species of shrimps contributed to the fishery and out of these, *Metapenaeus monoceros, M. dobsoni, Parapenaeopsis stylifera* and *Solenocera choprai* were the major constituents. Other species observed were *Metapenaeus affinis, Fenneropenaeus indicus, Penaeus monodon, P. canaliculatus, P. semisulcatus, Parapenaeus fissuroides*, *Aristeus alcockii* and *Heterocarpus gibbosus.* In 2003, *S. choprai* formed 38.55% of the total shrimp landing by trawlers (Table 1.9), *M. monoceros* contributed 20.50%. *P. stylifera* and *M. dobsoni* contributed 14.36% and 11.26% respectively. During the year, deep sea shrimp "red rings", *Aristeus alcocki* landing was 420 t which constituted 11.22% of shrimp landings by multi-day trawlers.

During 2004, 11 species represented the shrimp fishery of Mangalore-Malpe coast. *P. semisulcatus* was not observed in the fishery during this year, (Table 1.10). During the year *S. choprai* landing was reduced considerably and the landing of 'red rings' showed an increase. These changes had reflected in species composition *viz., M. monoceros* constituted 36.84% of the landings, *S. choprai* came down to 25.83% and 'red rings' contributed 11.42%. *M. dobsoni* and *P. stylifera* formed 11.55% and 7.20 % of the fishery respectively. The year-wise and harbour-wise species composition of shrimps landed at Mangalore and Malpe during 2003 and 2004 are given in Figs. 1.2 and 1.3.

4.1.1.3. *S. choprai* fishery in India

In India *S. choprai* is caught off Gujarat, Maharashtra, Karnataka and Kerala along the west coast and sporadic catches are reported from Tamil Nadu and Andhra Pradesh coast. No regular fishery exists for this species except in Karnataka and the landing in other parts of India is seasonal, represented by stray catches. During 2003-2004, total landing of the species in the country was about 2,700 t, (personal communication, G. Nandakumar, CMFRI) of which 86% was landed in Karnataka.

Along the Karnataka coast *S. choprai* started making an impact in the fishery economy from 1993 onwards. To understand the trend of *S. choprai* off Karnataka coast during preceding years, the catch data of the species during the last ten years were collected and analysed. During 1993, the landing was about 8 t which has increased to 3,186 t by 2002 (Fig. 1.4). It was observed that, it landed only at Mangalore and Malpe fisheries harbours and majority of the landing (87%) was at Mangalore. The annual average landing of *S. choprai* during 1993-2002 was 586 t forming 28.20% of the penaeid shrimp catch (Table 1.11). The percentage contribution of *S. choprai* in the shrimp fishery was less than 1% in 1993 and it rose to 56.60% in 2002 (Annual Report, CMFRI, 2002).

4.1.1.4. Fishing ground

S. choprai was caught from 60 m to 100 m depth off Mangalore and from the GPS readings collected from commercial trawlers, it was learned that the fishing area was between 74.10^0 to 74.50^0 E and 12.50^0 to 13.20^0 N (Fig.1.1). The fishing ground had sandy bottom which was very much suited for the burrowing habit of *S. choprai*. The fishing ground was much closer to Mangalore fisheries harbour (40 to 70 km) than Malpe (50 to 90 km).

4.1.1.5. Crafts and gears employed

S. choprai were caught in trawl nets operated from mechanised vessels. Multi-day fleet (MDF) trawlers of 9.75-15 m OAL (36-52 footer) fitted with engines of 53-102 hp made trips lasting up to 7 to 8 days and had fish-hold of varying capacity to store the catch in ice. The MDF used two types of nets *viz.,* shrimp trawl net during night and relatively bigger meshed fish trawl net during day. For *S. choprai* fishery, the fishermen use shrimp trawl nets which were slightly modified from the regular shrimp trawls. Here, more lead weights were added at the foot rope and were attached at closer intervals than those used for coastal shrimps. Some fishermen were attaching iron chains for disturbing the shrimps out of their burrows. The cod-end mesh size of shrimp net was 18-20 mm. By experience fishermen found that the catch is poor during day compared to night and presently trawling for *S. choprai* is conducted invariably during night.

4.1.1.6. Annual landing

During 2003, 28,167 multi-day trawl units landed 1,445 t of *S. choprai* at Mangalore and Malpe fisheries harbours. It formed 53% of the shrimp catch of multi-day trawlers (Table 1.12). When compared to the landing of 2002 (3,186 t), the catch showed a reduction of 55%. During 2004, 24,532 multi-day trawl units landed 752 t of *S. choprai* showing a reduction of about 693 t (Table 1.13). Even though the number of units put into operation was less during the year, the hours of fishing was more. On an average, each trawler unit spent 75 hours per operation as compared to 64 hours during the previous year.

4.1.1.7. Season-wise and month-wise catches

Overall, peak production of *S. choprai* along the Mangalore-Malpe coast was during August-September (post-monsoon season). During 2003, highest monthly landing was recorded in September and October and thereafter the catch decreased gradually till December. During August, the entire shrimp catch of the coast was constituted exclusively by *S. choprai.* During January another peak in landings was observed which again declined gradually (Fig. 1.5). In 2004 also similar trend was observed, the highest landing was in September (442 t) and thereafter the catch showed a declining trend. During this year also the entire shrimp landings during August was constituted by *S. choprai.* The percentage composition of the species in the shrimp fishery during September and October were 99% and 96% respectively.

4.1.1.8. *S. choprai* fishery at Mangalore

During 2003, 1,243 t of *S. choprai* with a catch rate of 65 kg per unit were landed at Mangalore fisheries harbour (Table 1.14). It formed 56% of the shrimp catch and 3% of the total all-fish catch by multi-day trawlers. During 2004, the landing declined to 734 t at a catch rate of 43 kg per unit. It constituted 35% of the shrimps landed by multi-day trawlers and 2% of the total all-fish landing (Table 1.15). A view of *S. choprai* landing at Mangalore fisheries harbour is given in Fig. 1.6.

4.1.1.9. *S. choprai* fishery at Malpe

At Malpe fisheries harbour, during 2003, 202 t of *S. choprai* were landed with a catch rate of 23 kg per unit. It formed 38% of the shrimp catch and about 1% of the total all-fish catch by multi-day trawlers (Table 1.16). During 2004, landing was only 18 t at a catch rate of 2 kg per unit (Table 1.17).

4.1.1.10. Marketing and disposal

S. choprai is having good demand in domestic market as well as for export. During 2003-2004, the average annual whole-sale price was Rs. 30 to 40 per kg. Considering an average price of Rs. 30 per kg, as the value realized, *S. choprai* fishery had contributed about Rs. 7 crores to the fishery economy of Karnataka during 2003-2004.

4.1.2. DISCUSSION

It is seen that during the past 40 years of trawling history of Karnataka, gradual changes have occurred especially in the depth of operation, duration of operation per fishing trip and species composition of the landing. In early sixties the depth of operation was up to 10 to 20 m (Kuthalingam *et al.*, 1966) and during 1967-1970 the depth of operation was extended up to 30 m (Ramamurthy, 1972). During 1970-1980, the depth of operation was further extended up to 40 m (Ramamurthy and Sukumaran, 1984) and during 1980-1985, trawlers were operated up to a depth of 55 m (Sukumaran, 1985). By 1985-1995, the depth of operation was extended up to 100 m, during which period the fishery of *S. choprai* also emerged (Sukumaran *et al.,* 1998). This indicated that the fishing ground of the species is beyond a depth of 55 m. Trawling was further extended up to 150 m by 2000 and from 2000 onwards some of the trawlers were equipped for deep sea trawling and operated in distant deeper waters of up to 500 m. (Dineshbabu *et al.*, 2001). It was reported that during 1992, the actual fishing hours per trip was around 29 which rose to 64 in 2003. Recent studies on the trawl fishery of Mangalore-Malpe coast (Zacharia *et al.*, 1996) have shown that single-day and multi-day shrimp trawlers are using trawl net with a cod end mesh size 10 and 15 mm respectively. But during the present study, use of slightly bigger mesh sizes (18-20 mm) has been observed for the capture of shrimps like *S. choprai*. Bigger mesh sizes enable faster movement of trawlers, while fishing in deeper waters.

Hashimi *et al.* (1978), Harkantra *et al.* (1980), Kidwai *et al.* (1981) and Shankar and Karbassi (1992) found that there is a patch of sandy region off South Karnataka extending from a depth of 50 to 200 m, and this type of sandy bottom is not seen anywhere in the west coast of India and the fishing ground for *S. choprai* falls within this region (60 to 100 m). This unique sandy bottom may be providing ideal habitat for the congregation of burrowing species like *S. choprai* and support unusually high catch of the species from this fishing ground. It is also observed that more than 80% of *S. choprai* is landed at Mangalore and the contribution from Malpe is very less. The fishing ground is located much closer to Mangalore fisheries harbour than Malpe, and trawlers from Malpe have to cruise an additional 20 to 40 km than those from Mangalore for fishing in this ground.

Analysing the trend of the fishery it was seen that, the catch and catch per unit was increasing rapidly till 2002. During 2002, the catch was 3,186 t by multi-day trawlers at a catch per unit of 112 kg. But during 2003, the catch showed a sharp decline to 1,445 t which is less than half of the previous year. Similar reduction was noticed in the catch rate also, which was reduced to 51 kg, which is again less than half of the preceding year. During 2004, the catch was further reduced to 752 t with catch rate showing further reduction.

Increase of catch per unit of shrimps with increasing effort shows that the ground is virgin and there is more potential to be tapped. But the sudden decline of the resource in total catch and catch per unit from such grounds requires a closer monitoring of the stock size and exploitation. Similar trend of sudden decline of fishery after showing increasing trend for some period was reported in the case of deep sea shrimps, *Aristeus alcockii* and *Heterocarpus* spp. along south Kerala coast by Nandakumar *et al.* (2001). Drastic reduction in overall catch and catch rate, in deep sea shrimp fishery during 2000-2001 season, after an increasing trend till 1999-2000 season was attributed to the over exploitation of the virgin fishing ground and also to the low fecundity of deep sea shrimps.

Present study revealed that *S. choprai* is caught in good quantity only during night, which shows that the species is nocturnal in habit. During day time these shrimps burrow deep into the sand. Similar behaviour was reported in the case of *S. acuminata* along the continental slope off French Guinea (Gueguen, 2001). *S. acuminata* was caught from the depth of 200 m only during night time and during day time the catch was dominated by another species, *Parapenaeus longirostris*.

It was also observed that the fluctuations in the landings of *S. choprai* in different months were influenced by various stock independent factors. Major stock independent factor for the fluctuation in the fishery is the change in targeted species during different months. *M. monoceros*, other larger shrimps and cephalopods were the major targeted groups which were preferred over *S. choprai* and when these resources are available, trawlers shift their operation to the fishing ground where preferred species are available.

Shrimps were the single group contributing the maximum value realization in the trawl fishery of Karnataka coast till early 1990s. Since the night trawling and multi-day trawling operations were introduced at depths beyond 40 m, the landing of *M. monoceros* increased substantially. Sukumaran (1982) estimated that during 1980-82 shrimps alone accounted for 70 to 75% of the value realised from the trawl fishery, even though they constituted only 13% of the trawl landing. After the extension of fishing beyond 60 m depth, the quantity of shrimps increased but the value realized did not show corresponding improvement (Zacharia *et al.*, 1996). *S. choprai* which dominated the landings from these depths (60 to 100 m) are having good market demand for local consumption and export. When compared with the other larger shrimp species like *M. monoceros*, the price for this species is low (30 to 40 rupees per kg), but considering the magnitude of the quantity landed, the contribution of the species to fishery economy of the Mangalore-Malpe region is substantial.

Table 1.1. Shrimp landing (t) by the multi-day trawlers at Mangalore fisheries harbour during 2003.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. semisulcatus*	*S. choprai*	*Parapenaeus sp.*	*Aristeus sp.*	*Heterocarpus spp.*	Total shrimps	Total trawl landing
JAN	31	2307	133836	0	0	0	0.19	41.31	0.03	0	240.10	0.25	76.39	3.85	362.13	4349.27
FEB	28	2346	133610	0	0	0	0	80.41	0.44	0	107.76	0.30	122.08	7.28	318.27	3680.98
MAR	31	1746	104894	0	0	0	0	103.85	0.26	0	24.01	0.08	0	0	154.95	2609.96
APR	30	2448	151032	0	0	3.39	0	122.74	1.75	0	30.32	0	0	0	158.20	4790.20
MAY	31	2393	139370	0	0	6.23	0	69.69	1.12	0	86.87	0	0	0	163.91	4277.64
JUN	10	500	30690	0	0	0	0	23.79	0.62	0	2.71	0	0	0	27.13	947.47
JUL	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0.00	0.00
AUG	9	135	9042	0	0	0	0	0	0	0	9.56	0	0	0	9.56	424.28
SEP	30	1849	124271	0	0	0	0	0.41	0	0	330.05	0	0	0	330.45	5504.97
OCT	31	1700	99474	0	0	0	0	0.52	0	0	263.42	0	2.71	0	266.65	4669.11
NOV	30	2085	118163	0	0	0	0	7.59	0	0	110.39	0	116.78	5.44	240.20	4582.60
DEC	31	1665	114722	0	0	0	1.42	19.48	0	7.97	37.49	0.00	102.74	5.49	174.59	2596.62
ANNUAL	**292**	**19174**	**1159104**	**0**	**0**	**9.62**	**1.61**	**469.79**	**4.22**	**7.97**	**1242.68**	**0.63**	**420.71**	**22.06**	**2206.04**	**38433.11**

Table 1.2. Shrimp landing (t) by single-day and multi-day trawlers at Mangalore fisheries harbour in 2003.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. semisulcatus*	*S. choprai*	*Parapenaeus sp.*	*Aristeus sp.*	*Heterocarpus spp.*	Total shrimps	Total trawl landing
JAN	31	4605	145328	53.37	0.71	0.62	62.02	41.31	0.03	0	240.10	0.25	76.39	3.85	478.66	4901.32
FEB	28	4536	144558	35.78	0.50	0.86	74.96	80.41	0.44	0	107.76	0.30	122.08	7.28	430.38	4090.78
MAR	31	4623	119278	35.54	8.85	8.90	84.11	103.85	0.26	0	24.01	0.08	0	0	292.34	3146.94
APR	30	4782	162702	17.66	0.45	5.21	89.22	122.74	1.75	0	30.32	0	0	0	267.55	5118.92
MAY	31	4904	151925	63.18	0.24	7.95	23.78	69.69	1.12	0	86.87	0	0	0	252.84	4630.16
JUN	10	1040	33390	21.67	0.54	2.78	2.23	23.79	0.92	0	2.71	0	0	0	54.64	1027.11
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	9	270	18084	0	0	0	0	0	0	0	9.56	0	0	0	9.56	424.28
SEP	30	2235	126202	2.83	0	0.08	1.61	0.41	0	0	330.05	0	0.0	0	334.97	5540.87
OCT	31	3746	109704	0	0	0	0	0.52	0	0	263.42	0	2.71	0	266.65	5066.59
NOV	30	3356	124519	2.10	0	0.52	0.09	7.59	0.49	0	110.39	0	116.78	5.44	243.40	4924.86
DEC	31	3202	122407	23.37	0	0.04	8.60	19.48	0	7.97	37.49	0	102.74	5.49	205.19	3041.18
ANNUAL	**292**	**37299**	**1258097**	**255.71**	**11.29**	**26.95**	**346.62**	**469.79**	**5.02**	**7.97**	**1242.68**	**0.63**	**420.71**	**22.06**	**2836.17**	**41913.01**

Table 1.3. Shrimp landing (t) by the multi-day trawlers at Malpe fisheries harbour in 2003.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. canaliculatus*	*S. choprai*	*Aristeus* sp.	*Hetero-carpus* spp	Total shrimps	Total trawl landing
JAN	29	940	69594	0	0.06	0.09	0	46.37	0.82	0	2.13	0	0	49.46	1516.39
FEB	27	761	56128	0	0	0	0	43.46	0.37	0	25.60	0	0	69.43	2111.66
MAR	25	855	65905	0	0	3.6	0	67.96	0.69	0	6.93	0	0	79.17	2283.08
APR	29	1212	86014	0	0.02	9.17	0	67.00	2.01	0	3.79	0	0	81.99	2590.11
MAY	29	1610	128144	0	0	11.64	0	60.17	1.65	0.819	1.74	0	0	76.02	3709.04
JUN	10	417	36190	0	0	1.79	0	5.63	0.08	0	1.93	0	0	9.43	1005.87
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	16	840	46888	0	0	0	0	0.0	0	0	0	0	0	0.00	2934.26
SEP	29	754	44249	0	0	0	0	0.0	0	0	65.66	0	0	65.66	5489.60
OCT	21	428	29543	0	0	0	0	0.0	0	0	94.67	0	0	94.67	1249.90
NOV	29	795	55460	0	0	0	0	0.0	0	0	0	0	0	0.00	1841.16
DEC	28	381	18183	0	0	0	0	6.33	0	0	0	0	0	6.33	210.70
ANNUAL	**272**	**8993**	**636298**	**0**	**0.08**	**26.29**	**0**	**296.90**	**5.62**	**0.819**	**202.44**	**0**	**0**	**532.16**	**24941.74**

Table 1.4. Shrimp landing (t) by single-day and multi-day trawlers at Malpe fisheries harbour in 2003.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. canaliculatus*	*S. choprai*	*Aristeus* sp.	*Hetero-carpus* spp	Total shrimps	Total trawl landing
JAN	29	3033	80059	43.63	1.73	2.11	27.46	46.37	0.89	0	2.13	0	0	124.31	2052.03
FEB	27	2862	66633	20.44	0.24	1.01	42.80	43.46	0.37	0	25.60	0	0	133.92	2593.87
MAR	25	2665	74955	17.47	0.60	5.11	35.67	67.96	0.69	0	6.93	0	0	134.41	2610.02
APR	29	3190	95904	17.54	0.63	11.17	42.91	67.00	2.01	0	3.79	0	0	145.05	2862.09
MAY	29	3789	139039	28.78	0.50	15.70	29.57	60.17	1.77	0.82	1.74	0	0	139.03	4016.51
JUN	10	847	38340	6.93	0.20	3.15	2.12	5.63	0.08	0	1.93	0	0	20.04	1031.69
JUL	0	0	0	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0
AUG	16	1635	50863	15.38	0.00	0.90	2.87	0	0	0	0	0	0	19.14	2988.51
SEP	29	1252	46739	10.32	0.70	0.15	2.65	0	0.14	0	65.66	0	0	79.61	5659.46
OCT	21	1403	34418	0.00	0.00	0.00	0	0	0	0	94.67	0	0	94.67	1742.49
NOV	29	2088	60132	0.16	0.09	0.03	0.30	0	0	0	0	0	0	0.58	2147.78
DEC	28	1949	26023	5.64	0.31	2.62	5.60	8.05	0	0	0	0	0	22.22	653.68
ANNUAL	**272**	**24713**	**713105**	**166.276**	**4.987**	**41.943**	**191.95**	**298.62**	**5.94**	**0.82**	**202.44**	**0**	**0**	**912.97**	**28358.14**

Table 1.5. Shrimp landing (t) by the multi-day trawlers at Mangalore fisheries harbour in 2004.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. canaliculatus*	*S. choprai*	*Parapen-aeus sp*	*Aristeus sp.*	*Hetero-carpus spp.*	Total shrimps	Total trawl landing
JAN	31	2118	135687	28.88	0	2.53	1.19	129.40	0.14	0	44.02	0	0	1.85	208.01	2914.82
FEB	29	1972	117682	33.25	0	8.03	0	104.89	0.26	0	32.96	0	79.27	0.00	258.66	3267.72
MAR	31	2484	143605	3.54	0	0.09	0.66	145.32	3.84	1.59	31.84	0	116.74	3.21	306.83	4832.25
APR	29	1496	129230	0	0	24.94	0	68.36	3.96	0.15	53.87	0	0	0	151.28	3685.88
MAY	27	1418	116748	0	0	4.16	0	22.01	0.71	0	16.92	0	0	0	43.80	2067.97
JUN	11	198	12052	0	0	0.69	0	4.05	0	0	4.54	0	0	0	9.28	227.46
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	14	372	32614	0	0	0	0	0	0	0	2.79	0	0	0	2.79	1165.15
SEP	30	1960	171470	0	0	0	0	0	0	0	440.15	0	0	0	440.15	15939.15
OCT	31	1643	131149	0	0	0	0	3.43	0	0	88.29	0	0	0	91.72	4434.81
NOV	30	1780	165655	0	0	0	0	0	0	0	11.88	0	0	0	11.88	3698.49
DEC	30	1585	129460	0	0	25.28	0	252.82	0.04	0	6.28	0	127.85	6.25	418.51	3655.53
ANNUAL	**293**	**17026**	**1285352**	**65.67**	**0**	**65.72**	**1.85**	**730.27**	**8.95**	**1.74**	**733.52**	**0**	**323.85**	**11.31**	**2072.35**	**45889.22**

Table 1.6. Shrimp landing (t) by single-day and multi-day trawlers at Mangalore fisheries harbour in 2004.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. canaliculatus*	*S. choprai*	*Parapen-aeus sp.*	*Aristeus sp.*	*Hetero-carpus spp.*	Total shrimps	Total trawl landing
JAN	31	4064	145418	59.88	0.11	5.57	13.13	129.40	0.14	0	44.02	0	0.00	1.85	254.11	3404.74
FEB	29	3785	126745	61.67	0	10.81	16.42	104.89	0.26	0	32.96	0	79.27	0.00	306.28	3660.98
MAR	31	4251	152440	36.14	0	4.96	28.37	145.32	3.84	1.59	31.84	0	116.74	3.21	372.01	5115.88
APR	29	3077	137133	30.96	0.74	26.72	11.84	68.36	3.96	0.15	53.87	0	0	0	196.59	3920.22
MAY	27	2468	122000	6.01	0	4.52	11.38	22.01	0.71	0	16.92	0	0	0	61.55	2155.12
JUN	11	423	13177	0.77	0	1.37	1.44	4.05	0	0	4.54	0	0	0	12.16	232.88
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	0	372	32614	0	0	0	0	0	0	0	2.79	0	0	0	2.79	1165.15
SEP	14	1960	171470	0	0	0	0	0	0	0	440.15	0	0	0	440.15	15939.15
OCT	30	1853	132199	0	0	0	0	3.43	0	0	88.29	0	0	0	91.72	4447.24
NOV	31	2125	167380	0.77	0	0	0	0.0	0	0	11.88	0	0	0	12.64	3722.21
DEC	30	2520	134135	19.95	0.23	25.69	7.77	252.82	0.04	0	6.28	0	127.85	6.25	418.51	3655.53
ANNUAL	**30**	**26898**	**1334711**	**216.14**	**1.07**	**79.65**	**90.35**	**730.27**	**8.95**	**1.74**	**733.52**	**0**	**323.85**	**11.31**	**2297.97**	**47419.09**

Table 1.7. Shrimp landing (t) by the multi-day trawlers at Malpe fisheries harbour in 2004.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*S. choprai*	*Parapenaeus* sp.	*Aristeus* sp.	*Heterocarpus* spp	Total shrimps	Total trawl landing
JAN	29	633	45264	0.31	0	0.08	0.05	48.76	0.15	0	0	0	0	49.35	1034.08
FEB	27	833	64301	0	0	0.24	0	60.07	0.05	0	0	0	0	60.36	1189.97
MAR	30	844	63274	0	2.44	0	45.45	0.10	0	5.58	0	7.71	0	61.28	1195.34
APR	27	815	64681	0	0	7.45	0.13	41.35	1.13	3.07	0	0	0	53.13	1531.39
MAY	25	760	48605	8.89	0	5.92	3	59.73	0.22	3.95	0.32	0	0	82.02	1407.84
JUN	10	315	25245	0	0	14.44	0	18.63	1.50	0.52	0	0	0	35.08	1097.92
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	14	266	21714	0	0	0	0	0	0	0	0	0	0	0	584.23
SEP	27	824	64773	0	0.90	0	0	0	0	1.85	0	0	0	2.75	4295.70
OCT	30	1044	69378	0	0	0	0	0	0	2.41	0	0.56	0	2.98	2276.77
NOV	28	667	49560	0	0	0	0	0	0	0	0	0	0	0.0	1206.43
DEC	29	505	35165	0.52	0	3.45	0.394	111.90	0.11	0.73	0	0.20	0	117.31	688.19
ANNUAL	**276**	**7506**	**551960**	**9.72**	**3.34**	**31.58**	**49.022**	**340.54**	**3.15**	**18.09**	**0.32**	**8.48**	**0**	**464.23**	**16507.85**

Table 1.8. Shrimp landing (t) by single-day and multi-day trawlers at Malpe fisheries harbour in 2004.

MONTH	Fishing days	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*S. choprai*	*Parapenaeus* sp.	*Aristeus* sp.	*Heterocarpus* spp	Total shrimps	Total trawl landing
JAN	29	1851	51354	20.99	0.74	1.14	5.87	49.70	0.15	0	0	0	0	72.77	1381.43
FEB	27	2674	73506	16.40	0.63	9.87	10.64	60.07	0.05	0	0	0	0	87.01	1696.21
MAR	30	2601	72059	11.82	2.59	8.67	59.43	0.10	0	5.6	0	7.71	0	81.93	1582.66
APR	27	2107	71139	11.80	2.12	7.98	12.29	41.35	1.13	3.1	0	0	0	67.58	1742.93
MAY	25	2115	55380	30.06	0	7.33	17.49	59.73	0.22	3.9	0.32	0	0	104.59	1589.33
JUN	10	531	26325	5.18	0.04	15.84	1.51	18.63	1.50	0.5	0	0	0	41.71	1113.30
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	14	853	24647	3.74	0	1.86	1.76	0	0	0	0	0	0	5.60	812.75
SEP	27	1074	66023	0.06	1.14	0.01	0	0.02	0	1.85	0	0	0	3.07	4497.39
OCT	30	1812	73218	0	0	0	2.54	0	0	2.41	0	0.56	0	2.98	2552.50
NOV	28	1288	52665	5.12	0.07	0.01	0.37	0	0	0	0	0	0	5.19	1243.83
DEC	29	1367	39475	14.62	0.39	4.12	7.19	111.90	0.11	0.73	0	0.20	0	139.26	874.78
ANNUAL	**276**	**18273**	**605791**	**119.79**	**7.72**	**56.81**	**119.09**	**341.49**	**3.15**	**18.09**	**0.32**	**8.48**	**0**	**611.67**	**19087.08**

Table 1.9. Total shrimp landing (t) by trawlers at Mangalore-Malpe fisheries harbours in 2003.

MONTH	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. semisulcatus*	*P. canaliculatus*	*S. choprai*	*Parapen-aeus sp.*	*Aristeus sp.*	*Hetero-carpus spp*	Total shrimps	Total trawl landing
JAN	7638	225387	97.00	2.44	2.72	89.48	87.68	0.91	0	0	242.23	0.25	76.39	3.85	602.97	6953.35
FEB	7398	211191	56.22	0.75	1.87	117.76	123.87	0.82	0	0	133.35	0.30	122.08	7.28	564.30	6684.65
MAR	7288	194233	53.01	9.44	14.01	119.77	171.80	0.95	0	0	30.93	0.08	0	0	426.75	5756.96
APR	7972	258606	35.40	1.08	16.38	132.13	189.74	3.75	0	0	34.12	0	0	0	412.59	7981.01
MAY	8693	290964	91.96	0.73	23.65	53.35	129.86	2.89	0	0.82	88.61	0	0	0	391.87	8646.67
JUN	1887	71730	28.59	0.74	5.93	4.35	29.42	1.01	0	0	4.64	0	0	0	74.68	2058.80
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	1905	68947	15.38	0	0.90	2.87	0	0	0	0	9.56	0	0	0	28.70	3412.80
SEP	3487	172941	13.15	0.70	0.23	4.26	0.41	0.14	0	0	395.70	0	0	0	414.58	11200.34
OCT	5149	144122	0	0	0	0	0.52	0	0	0	358.09	0	2.71	0	361.32	6809.08
NOV	5444	184651	2.27	0.09	0.55	0.39	7.59	0.49	0	0	110.39	0	116.78	5.44	243.98	7072.64
DEC	5151	148430	29.01	0.31	2.66	14.20	27.53	0	7.97	0	37.49	0	102.74	5.49	227.40	3694.86
ANNUAL	**62012**	**1971202**	**421.98**	**16.27**	**68.89**	**538.56**	**768.41**	**10.96**	**7.97**	**0.82**	**1445.12**	**0.63**	**420.71**	**22.06**	**3749.14**	**70271.15**
Catch per unit (kg)			6.80	0.26	1.11	8.68	12.39	0.18	0.13	0.01	23.30	0.01	6.78	0.36	60.46	1133.19
Percentage in shrimp catch			11.26	0.43	1.84	14.36	20.50	0.29	0.21	0.02	38.55	0.02	11.22	0.59	*	*
Percentage in total all-fish catch			0.60	0.02	0.10	0.77	1.09	0.02	0.01	0.00	2.06	0.00	0.60	0.03	5.34	*

Table 1.10. Total shrimp landing (t) by trawlers at Mangalore-Malpe fisheries harbours in 2004.

MONTH	Fishing units	Fishing hours	*M. dobsoni*	*M. affinis*	*F. indicus*	*P. stylifera*	*M. monoceros*	*P. monodon*	*P. semisulcatus*	*P. canaliculatus*	*S. choprai*	*Parapen-aeus sp.*	*Aristeus sp.*	*Hetero-carpus spp*	Total shrimps	Total trawl landing
JAN	5915	196772	80.87	0.86	6.71	19.01	179.11	0.28	0	0	44.02	0	0	1.85	326.88	4786.17
FEB	6459	200251	78.07	0.63	20.68	27.06	164.95	0.31	0	0	32.96	0	79.27	0	393.30	5357.19
MAR	6852	224499	47.97	2.59	13.63	87.80	145.42	3.84	0	1.59	37.42	0	124.45	3.21	453.93	6698.54
APR	5184	208272	42.76	2.86	34.70	24.13	109.71	5.09	0	0.15	56.94	0	0	0	264.17	5663.14
MAY	4583	177380	36.07	0	11.85	28.87	81.74	0.93	0	0	20.87	0.32	0	0	166.14	3744.45
JUN	954	39502	5.95	0.04	17.21	2.95	22.68	1.50	0	0	5.06	0	0	0	53.87	1346.18
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	1225	57261	3.74	0	1.86	1.76	0	0	0	0	2.79	0	0	0	8.39	1977.89
SEP	3034	237493	0.06	1.14	0.01	0	0.02	0	0	0	441.99	0	0	0	443.21	20436.54
OCT	3665	205417	0	0	0	2.54	3.43	0	0	0	90.71	0	0.56	0	94.70	6999.74
NOV	3413	220045	5.88	0.07	0.01	0.37	0	0	0	0	11.88	0	0	0	17.83	4966.04
DEC	3887	173610	34.57	0.61	29.80	14.95	364.72	0.15	0	0	7.00	0	128.05	6.25	557.76	4530.30
ANNUAL	**45171**	**1940502**	**335.93**	**8.79**	**136.46**	**209.43**	**1071.77**	**12.09**	**0**	**1.74**	**751.62**	**0.32**	**332.33**	**11.31**	**2909.64**	**66506.17**
Catch per unit (kg)			7.44	0.19	3.02	4.64	23.73	0.27	0	0.04	16.64	0.01	7.36	0.25	64.41	1472.32
Percentage in shrimp catch			11.55	0.30	4.69	7.20	36.84	0.42	0	0.06	25.83	0.01	11.42	0.39	*	*
Percentage in total all-fish catch			0.51	0.01	0.21	0.31	1.61	0.02	0	0.00	1.13	0.00	0.50	0.02	4.37	*

Table 1.11. *S. choprai* landing at Mangalore and Malpe fisheries harbours during 1993-2002.

Year	Mangalore		Malpe		Total
	landing (t)	Percentage	landing (t)	Percentage	landing (t)
1993	7.85	100	0	0	7.85
1994	100.96	100	0	0	100.96
1995	171.61	100	0	0	171.61
1996	164.48	98.16	3.08	1.84	167.56
1997	258.15	92.35	21.39	7.65	279.54
1998	227.50	75.51	73.80	24.49	301.30
1999	368.30	97.95	7.70	2.05	376.00
2000	498.30	92.16	42.40	7.84	540.70
2001	1550.80	84.22	290.60	15.78	1841.40
2002	2745.70	86.18	440.30	13.82	3186.00

Table 1.12. Details of the catch of *S. choprai* landed (by MDF) at Mangalore and Malpe fisheries harbours in 2003.

MONTH	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)	Catch per unit (kg)	Catch per hour (kg)	Percentage in shrimps	Percentage in trawl catch
JAN	3247	203430	242.23	411.59	5865.66	74.60	1.19	58.853	4.13
FEB	3107	189738	133.35	387.70	5792.64	42.92	0.70	34.396	2.30
MAR	2601	170799	30.93	234.11	4893.04	11.89	0.18	13.212	0.63
APR	3660	237046	34.12	240.19	7380.31	9.32	0.14	14.204	0.46
MAY	4003	267514	88.61	239.93	7986.68	22.14	0.33	36.933	1.11
JUN	917	66880	4.64	36.56	1953.35	5.06	0.07	12.693	0.24
JUL	0	0	0	0	0	0	0.0	0	0
AUG	975	55930	9.56	9.56	3358.54	9.81	0.17	100.000	0.28
SEP	2603	168520	395.70	396.11	10994.56	152.02	2.35	99.897	3.60
OCT	2128	129017	358.09	361.32	5919.01	168.27	2.78	99.105	6.05
NOV	2880	173623	110.39	240.20	6423.76	38.33	0.64	45.957	1.72
DEC	2046	132905	37.49	180.93	2807.32	18.32	0.28	20.722	1.34
ANNUAL	**28167**	**1795402**	**1445.12**	**2738.20**	**63374.85**	**51.31**	**0.80**	**52.776**	2.28

Table 1.13. Details of the catch of *S. choprai* landed (by MDF) at Mangalore and Malpe fisheries harbours in 2004.

MONTH	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)	Catch per unit (kg)	Catch per hour (kg)	Percentage in shrimps	Percentage in trawl catch
JAN	2751	180951	44.02	257.37	3948.90	16.0	0.24	17.10	1.11
FEB	2805	181983	32.96	319.02	4457.68	11.8	0.18	10.33	0.74
MAR	3328	206879	37.42	368.11	6027.60	11.2	0.18	10.16	0.62
APR	2311	193911	56.94	204.40	5217.27	24.6	0.29	27.86	1.09
MAY	2178	165353	20.87	125.81	3475.80	9.6	0.13	16.58	0.60
JUN	513	37297	5.06	44.35	1325.38	9.9	0.14	11.40	0.38
JUL	0	0	0	0	0	0		0	0
AUG	638	54328	2.79	2.79	1749.38	4.4	0.05	100.00	0.16
SEP	2784	236243	441.99	442.89	20234.85	158.8	1.87	99.80	2.18
OCT	2687	200527	90.71	94.70	6711.58	33.8	0.45	95.78	1.35
NOV	2447	215215	11.88	11.88	4904.91	4.9	0.06	100.00	0.24
DEC	2090	164625	7.00	665.27	4343.72	3.4	3.4	1.05	0.16
ANNUAL	**24532**	**1837312**	**751.62**	**2536.58**	**62397.06**	**30.6**	**0.4**	**29.63**	**1.20**

Table 1.14. *S. choprai* landing by multi-day trawlers at Mangalore fisheries harbour in 2003.

MONTH	No. of. Fishing days	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)
JAN	31	2307	133836	240.10	362.13	4349.27
FEB	28	2346	133610	107.76	318.27	3680.98
MAR	31	1746	104894	24.01	154.95	2609.96
APR	30	2448	151032	30.32	158.20	4790.20
MAY	31	2393	139370	86.87	163.91	4277.64
JUN	10	500	30690	2.71	27.13	947.47
JUL	0	0	0	0	0	0
AUG	9	135	9042	9.56	9.56	424.28
SEP	30	1849	124271	330.05	330.45	5504.97
OCT	31	1700	99474	263.42	266.65	4669.11
NOV	30	2085	118163	110.39	240.20	4582.60
DEC	31	1665	114722	37.49	174.59	2596.62
ANNUAL	**292**	**19174**	**1159104**	**1242.68**	**2206.04**	**38433.11**
Catch per unit of *S.choprai* (kg)						**64.81**
Percentage in shrimp catch						**56.33**
Percentage in total all-fish catch						**3.23**

Table 1.15. *S. choprai* landing by multi-day trawlers at Mangalore fisheries harbour in 2004.

MONTH	No. of. Fishing days	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)
JAN	31	2118	135687	44.02	208.01	2914.82
FEB	29	1972	117682	32.96	258.66	3267.72
MAR	31	2484	143605	31.84	306.83	4832.25
APR	29	1496	129230	53.87	151.28	3685.88
MAY	27	1418	116748	16.92	43.80	2067.97
JUN	11	198	12052	4.54	9.28	227.46
JUL	0	0	0	0	0	0
AUG	14	372	32614	2.79	2.79	1165.15
SEP	30	1960	171470	440.15	440.15	15939.15
OCT	31	1643	131149	88.29	91.72	4434.81
NOV	30	1780	165655	11.88	11.88	3698.49
DEC	30	1585	129460	6.28	547.97	3655.53
ANNUAL	**293**	**17026**	**1285352**	**733.52**	**2072.35**	**45889.22**
Catch per unit of *S.choprai* (kg)						**43.08**
Percentage in shrimp catch						**35.40**
Percentage in total all-fish catch						**1.60**

Table 1.16. *S. choprai* landing by multi-day trawlers at Malpe fisheries harbour in 2003.

MONTH	No. of. Fishing days	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)
JAN	29	940	69594	2.13	49.46	1516.39
FEB	27	761	56128	25.60	69.43	2111.66
MAR	25	855	65905	6.93	79.17	2283.08
APR	29	1212	86014	3.79	81.99	2590.11
MAY	29	1610	128144	1.74	76.02	3709.04
JUN	10	417	36190	1.93	9.43	1005.87
JUL	0	0	0	0	0	0
AUG	16	840	46888	0	0	2934.26
SEP	29	754	44249	65.66	65.66	5489.60
OCT	21	428	29543	94.67	94.67	1249.90
NOV	29	795	55460	0.00	0.00	1841.16
DEC	28	381	18183	0.00	6.33	210.70
ANNUAL	**272**	**8993**	**636298**	**202.44**	**532.16**	**24941.74**
Catch per unit of *S.choprai* (kg)						**22.51**
Percentage in shrimp catch						**38.04**
Percentage in total all-fish catch						**0.81**

Table 1.17. *S. choprai* landing by multi-day trawlers at Malpe fisheries harbour in 2004.

MONTH	No. of. Fishing days	No. of. fishing units	No. of. fishing hours	*S. choprai* landing (t)	Total shrimp landing (t)	Total trawl landing (t)
JAN	29	633	45264	0	49.35	1034.08
FEB	27	833	64301	0	60.36	1189.97
MAR	30	844	63274	5.58	61.28	1195.34
APR	27	815	64681	3.07	53.13	1531.39
MAY	25	760	48605	3.95	82.02	1407.84
JUN	10	315	25245	0.52	35.08	1097.92
JUL	0	0		0	0	0
AUG	14	266	21714	0	0	584.23
SEP	27	824	64773	1.85	2.75	4295.70
OCT	30	1044	69378	2.41	2.98	2276.77
NOV	28	667	49560	0.00	0.00	1206.43
DEC	29	505	35165	0.73	117.31	688.19
ANNUAL	**276**	**7506**	**551960**	**18.09**	**464.23**	**16507.85**
Catch per unit of *S.Choprai* (kg)						**2.41**
Percentage in shrimp catch						**3.90**
Percentage in total all-fish catch						**0.11**

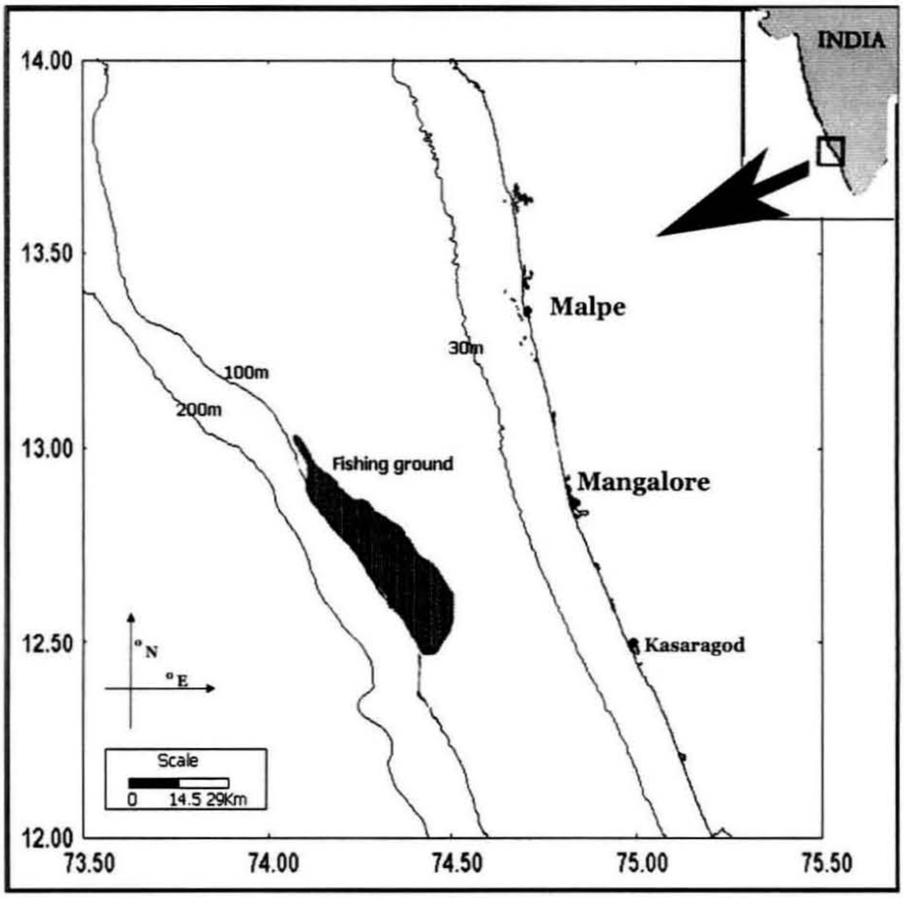
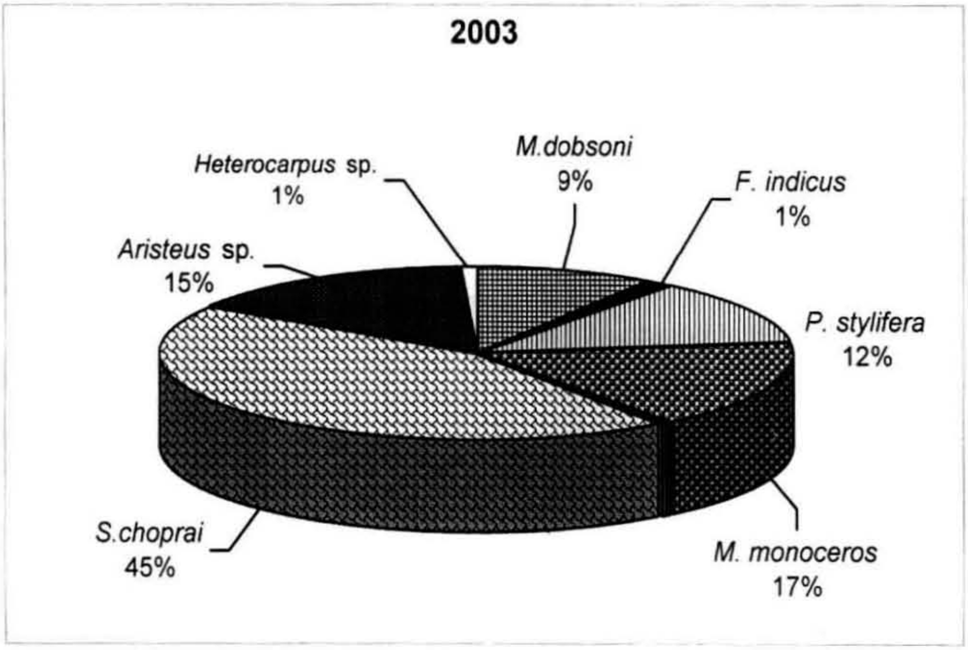


Fig. 1.1. Map showing the fishing ground for *S. choprai*.



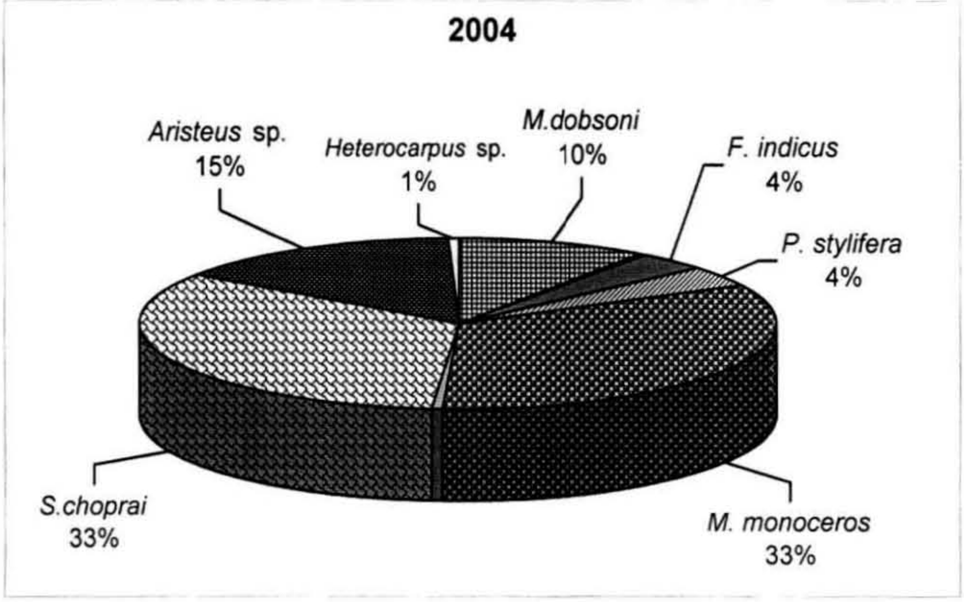
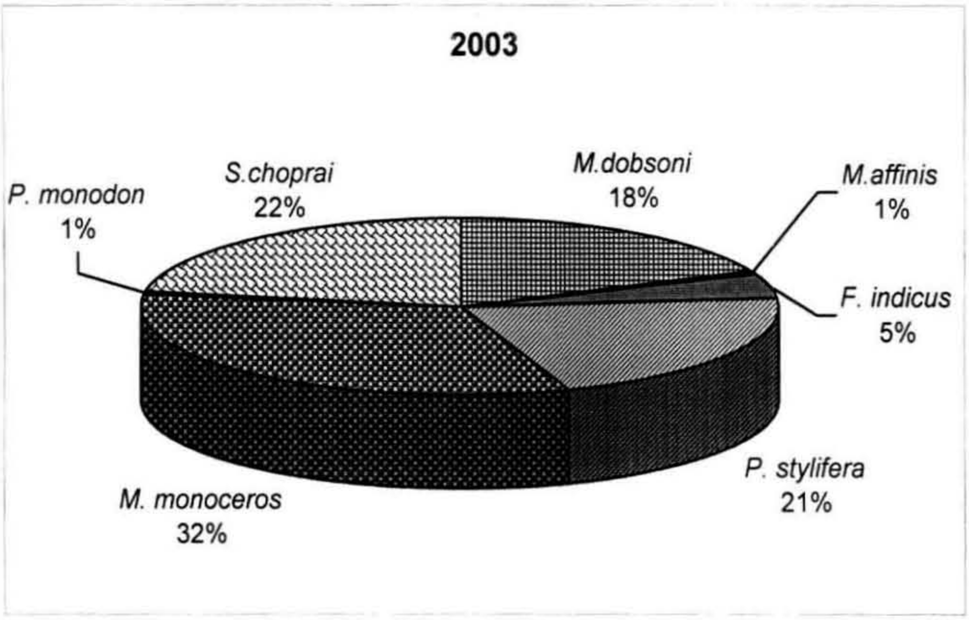


Fig. 1.2. Species compositions of shrimps landed at Mangalore fisheries harbour during 2003 and 2004.



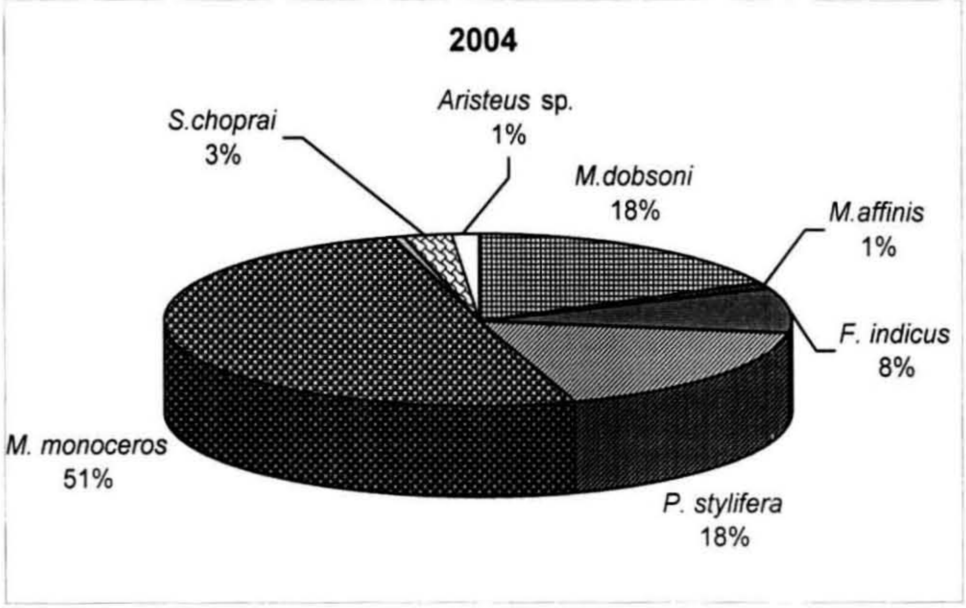


Fig. 1.3. Species compositions of shrimps landed at Malpe fisheries harbour during 2003 and 2004.

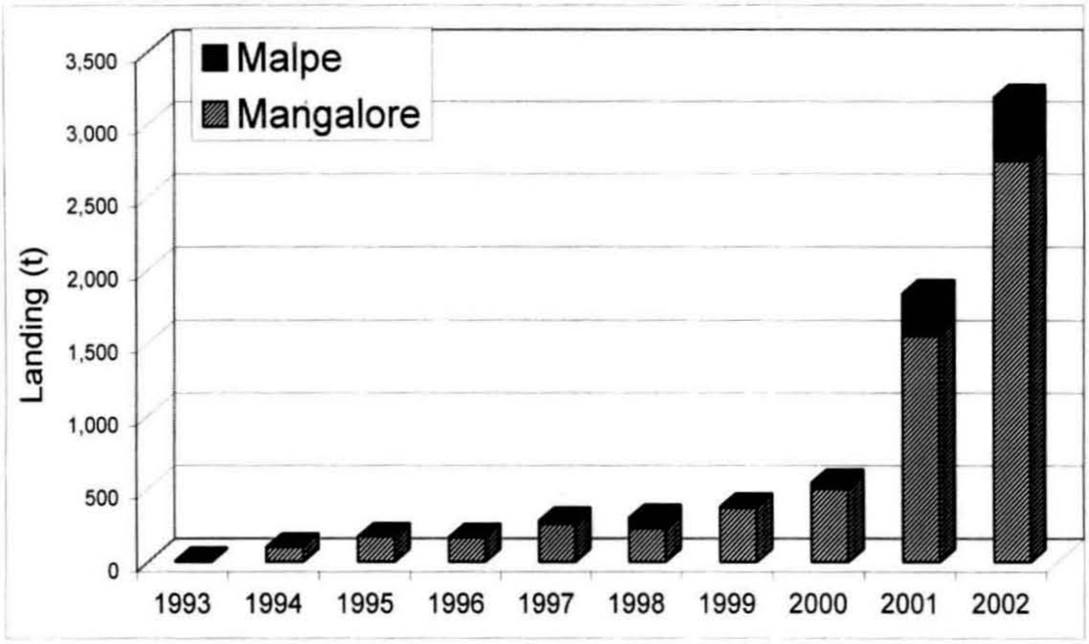


Fig. 1.4. Landing of *S. choprai* at Mangalore and Malpe fisheries harbours during 1993-2002.

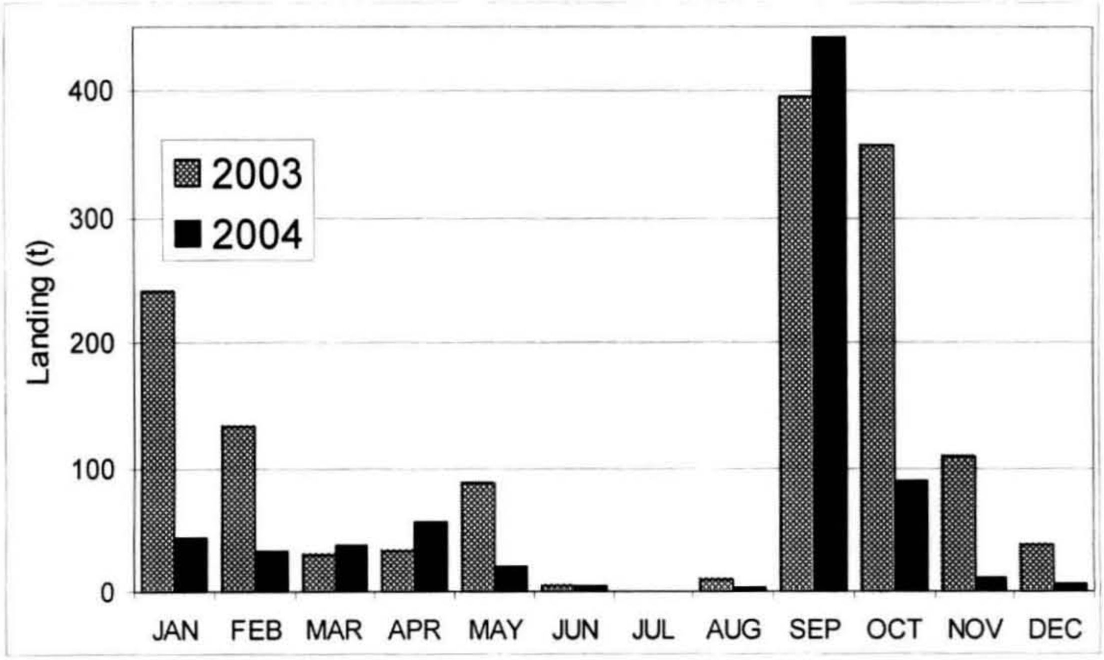


Fig. 1.5. Month-wise landing of *S. choprai* at Mangalore and Malpe fisheries harbours during 2003and 2004.

Fig. 1.6. A view of *S. choprai* landing at Mangalore fisheries harbour.

4.2. Taxonomy

4. 2. TAXONOMY

4.2.1. RESULTS

S. choprai being a non conventional shrimp resource from Indian coast, detailed macroscopic and microscopic examinations were conducted on the morphology to study its systematic position before carrying out the biological studies.

4.2.1.1. Description of the Genus

Genus: ***Solenocera*** H. Lucas, 1849.

Moderately robust, medium sized shrimps, with firm cuticle; pereopods well developed, pleopod not exceptionally long. Carapace smooth except for the rostral area which is setose (Fig. 2.2) Antennular flagella wide and when apposed forming a respiratory tube (Fig. 2.3), the antennular flagella often as long as or longer than the carapace. Rostrum laterally compressed, usually deep and not exceeding the first segment of the antennular peduncle and with dorsal teeth only. Inner border of the eyestalk bears a tubercle. Post orbital, antennal and hepatic spines present. Cervical sulcus reaching to or almost reaching to the dorsal mid line. First and second abdominal somites narrowing towards the dorsal midline, so that the cephalothorax can be flexed up almost at right angles to the abdomen. Exopods present on the thoracic somites 1 to 7. Telson usually armed with fixed sub-epical spine. In males, endopod of second pair of pleopods with appendix masculina, appendix interna and lateral projections.

4.2.1.2. Description of the Species

Species: ***Solenocera choprai*** Nataraj, 1945

(History: Solenocera choprai Nataraj, 1945: George, 1969; Starobogatov, 1972; Tirmizi, 1972; Crosnier, 1978, 1984, 1989, 1994; Grey et al., 1983; De freitas, 1985; Kensley, Tranter and Griffin, 1987.

Solenocera alticarinata Hall, 1961, 1962.

Solenocera koelbeli *Burkenroad, 1959.)*

Colour of the body, pereopods and pleopods are red. Antennae banded with dark red and white. Uropods are dark red except for some white and yellow areas (Fig. 2.1). Carapace including rostrum is slightly more than one third of total length. Carapace and abdomen are hairless except at the base of rostrum where it is distinctly pubescent; rostrum reaching middle to the $3/4^{th}$ of eye. Rostrum is gently convex on the upper margin and armed with seven to eight teeth (Fig. 2.2). The tip is gently tilted upwards and reaches to the middle of basal segment of the antennular peduncle. The teeth on the rostrum become smaller and gradually more closely spaced from back to forwards. The three posterior teeth are on the carapace, fourth is in level with the orbit and the rest are on the free stylar portion of the rostrum. The ventral margin of the rostrum is deeply convex, toothless and is fringed with a layer of long hairs. Post-rostral carina is distinct and continues almost to the posterior margin of the carapace interrupted by deep but narrow notch at the level of the cervical groove. This notch is in the midway between the tip of the rostrum and posterior end of carapace. The height of posterior part of rostral crest progressively decreases posteriorly. A little behind and below orbital angle is a distinct post-orbital spine. The antennal spine is large. The hepatic spine though smaller than antennular spine, is very acute.

The pubescent region of the sides of the rostrum is delimited ventrally by a faint lateral depression originating from the cervical notch of the post-rostral carina and the penultimate rostral tooth and runs obliquely forward towards the orbital angle. Between post orbital spine and the rostrum is a small but well defined depression. Cervical groove is deep on the sides and continues dorsally with that of the other side through the notch on post-rostral carina. The cervical ridge fades indistinguishably at the dorsal region just behind and below post-orbital notch. From the base of the post-orbital spine originates a deep narrow groove which runs vertically downwards and joins the sub-hepatic groove just below the hepatic spine. From the base of the hepatic spine, cervical groove continues horizontally backwards to some distance and then curves down ventrally towards the inferior margin of the carapace, thus setting off the region of oscillation of the scaphognathite, more or less like an oval area. The cervical groove is continued posteriorly as the branchiostegal sulcus which bends upwards where it fades away at some distance from the posterior border of the carapace (Fig. 2.2). Telson is sulcate mid-dorsally above a level of the lateral spine. The single pair of lateral teeth on the telson is short, fixed and slightly divergent. Antennular flagellum is as long as carapace with rostrum and tapers abruptly towards broadly rounded end. The inferior flagellum is nearly twice as wide as the superior one (Fig. 2.3).

The two halves of the petasma are united anteriorly each terminating at its distal end in three lobes which are armed along their free distal margins with minute spines (Fig. 2.4). The anterior lobule is broadly truncate and the middle broadly rounded. These two are united at their distal margins. The posterior lobe which is thick and narrow is free from its middle and its free distal portion lies inside the median lobe. The free end of this lobe is thick and narrow with an expanded hook-like distal margin which is curved outwards. Dorso-lateral lobules of the petasma bear 20 to 30 terminal spinules. Dorso-median lobules also bear same number of spinules whereas, disto-lateral lobules have 12-18 spinules (Fig. 2.4).

The thelycum consists of the following: the sternum between the third pair of pereopods is raised into a pair of vertical plate like structure, the inner margins of which are in close contact with one another. There is a rounded median sternal prominence between the third and the fourth pair of pereopods. Between the coxa of the fourth pair of pereopods is a pair of inwardly directed narrow vertical plates, the distal margins of which are closely arranged. Below these plates, the sternum is hollowed out into a pit. In front of this pit is a pair of small sternal prominences. Median pair is larger than the lateral one. The sternum between the bases of the fifth pair of pereopods is produced posteriorly into a broad vertical trapezoid plate. Anteriorly it is cut into a trapezoid pit (Fig. 2.5).

4.2.1.3. Systematic position of *Solenocera choprai*

In the light of the results obtained from the present taxonomical studies and consultation of the literature from various authors, (George, 1969; Holthuise, 1980; Miquel, 1984; Chan, 1998 and Dall, 1999), the taxonomical position of *Solenocera choprai* is described as below.

Phylum	:	**Arthropoda**
Class	:	**Crustacea**
Subclass	:	**Malacostraca**
Series	:	**Eumalacostraca**
Superorder	:	**Eucarida**
Order	:	**Decapoda**
Sub-order	:	**Dendrobrachiata.**
Infraorder	:	**Penaeidae**
Superfamily	:	**Penaeoidea**
Family	:	**Solenoceridae Wood-Mason & Alcock, 1891**
Genus	:	***Solenocera* H. Lucas 1849**
Species	:	***Solenocera choprai* Nataraj, 1945**

4.2.2. DISCUSSION

S. choprai is widely distributed in the Indo-Pacific, from eastern coast of Africa, Madagascar, Gulfs of Suez and Arabia, Pakistan, India, Malaysia, Philippines, Indonesia, Taiwan, Thailand and northeast and northwest Australia (De freitas, 1985; Tirmizi, 1972; Crosnier, 1989 and Dall, 1999).

The species of *Solenocera* genus are inhabitants of the continental shelf and slope from about 15 m down to several hundred meters, some times to greater depths. The body form suggests that they are predominantly benthic and environmental data for a few species indicate that soft substrates are preferred. Long respiratory tube and ability to flex the cephalothorax upwards almost 90° to the abdomen, indicates that they bury deeply in these soft sediments (Dall, 1999). *S. choprai* found on soft bottoms at the depth between 50 and 175 m probably burrows in the mud during daytime, with only tube-like antennular flagella sticking out for respiration (Chan, 1998). During the present study, *S. choprai* was caught along Karnataka coast from a depth of 60 to 100 m, the fishing grounds were found to have sandy bottom (Hashimi *et al.*, 1978; Harkantra *et al.*, 1980; Kidwai *et al.*, 1981 and Shankar and Karbassi, 1992) and fishing was done exclusively during night time to exploit their nocturnal behaviour.

From Indian waters several authors described the distribution of species belonging to *Solenocera* genus (Nataraj, 1945; George, 1966; Mohamed, 1973 and Kurien and Sebastian, 1976). The distinguishable characters of *S. choprai* from all other reported species were investigated in the present study. *Solenocera crassicornis* is the commercially most important *Solenocera* species in India, which is distributed relatively at lower depth of 10 to 40 m along northwest coast of India. *S. crassicornis* is smaller than *S. choprai* in size (Miquel, 1984) and the post-rostral crest is low and rounded. The telson is smooth without lateral spines, whereas in *S. choprai* post-rostral crest is markedly elevated and laminose and telson is having a pair of lateral spines. Another species of commercial importance is *S. hextii* Wood Mason & Alcock, 1891, which was also landed at Mangalore fisheries harbour during the period of study. They were caught from a depth beyond 150 m. This species can be distinguished from *S. choprai* by the 'L' shaped branchiocardiac crest. Suprahepatic spine is present in *S. hextii* whereas in *S. choprai,* it is absent. Other species are caught in stray numbers from Indian waters. Out of these, *S. pectinata* (Spence Bate, 1988) was reported to have a rostrum with 8 to 9 densely packed small upper teeth (Chan, 1998). In *S. choprai* only three to four teeth are present on the rostrum. Nataraj (1945) described the presence of *S. melentho* de Man, 1907 along the Indian coast. He stated that *S. melentho* differs from *S. choprai* in the nature of cervical groove, which in *S. choprai* cuts the post-rostral carina deeply and in *S. melentho* does not. In the case of *S. alticarinata* Kubo, 1949, the posterior part of the rostral crest behind the cervical notch is distinctly higher than anterior part (Chan, 1998) whereas in *S. choprai* height of the posterior part of the post rostral carina progressively decreases. *S. koelbeli* De Man, 1911, is another species caught in stray numbers along the Indian coast. This species is distinguished from *S. choprai* by its characteristic post-rostral crest. Post-rostral crest in *S. koelbeli* is continuous, uninterrupted by cervical furrow (Nataraj, 1945; Chan, 1998) whereas, in *S. choprai* it is plate like and is interrupted by a cervical groove.

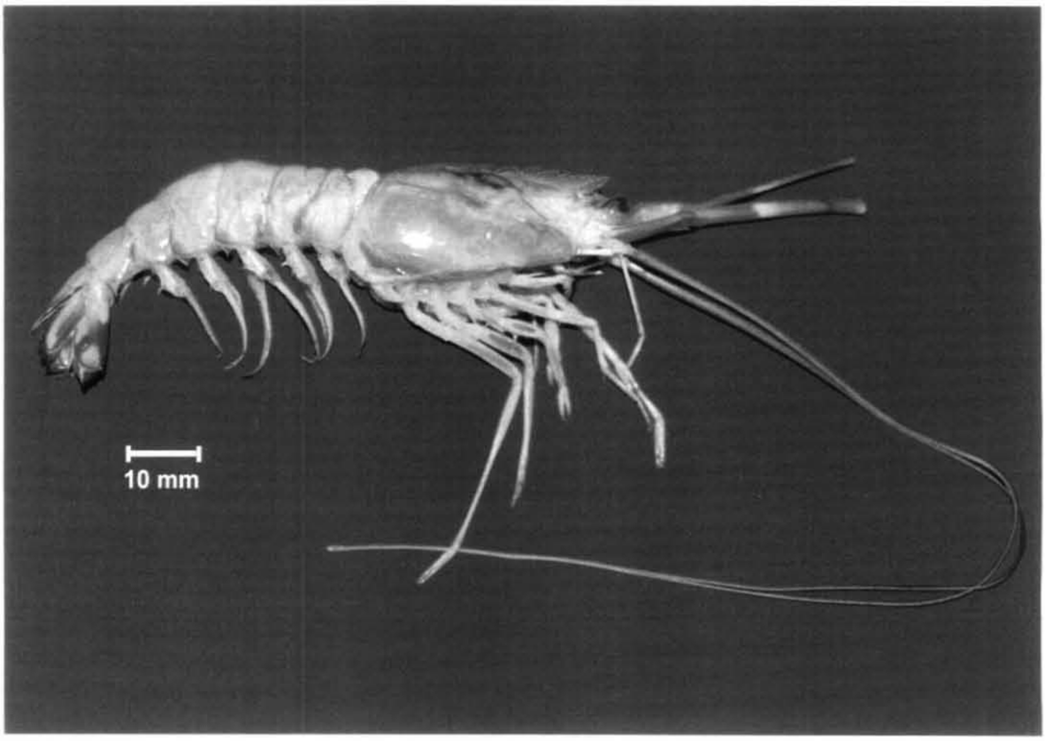


Fig. 2.1. *Solenocera choprai*, Nataraj, 1945.

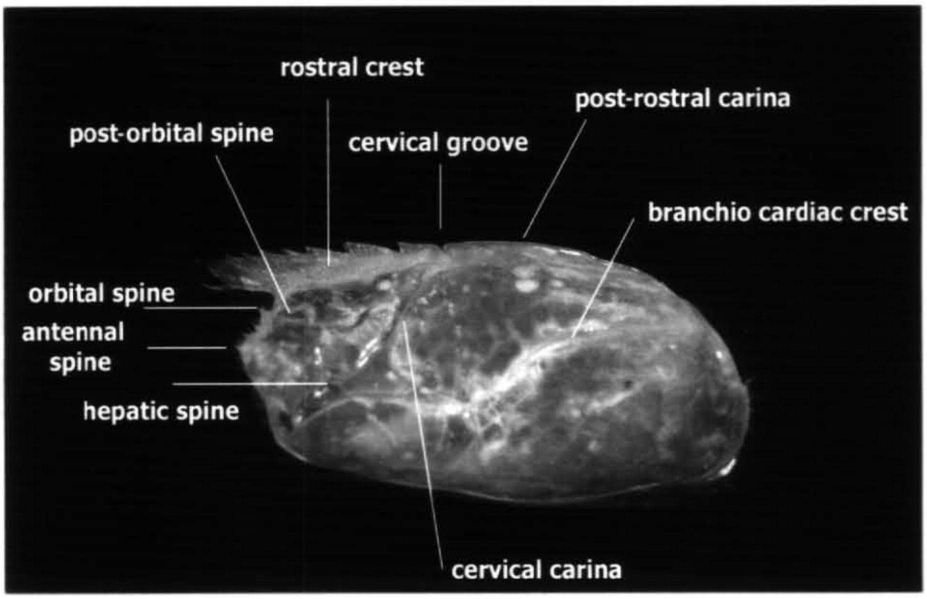


Fig. 2.2. Diagnostic features of carapace of *S. choprai*.

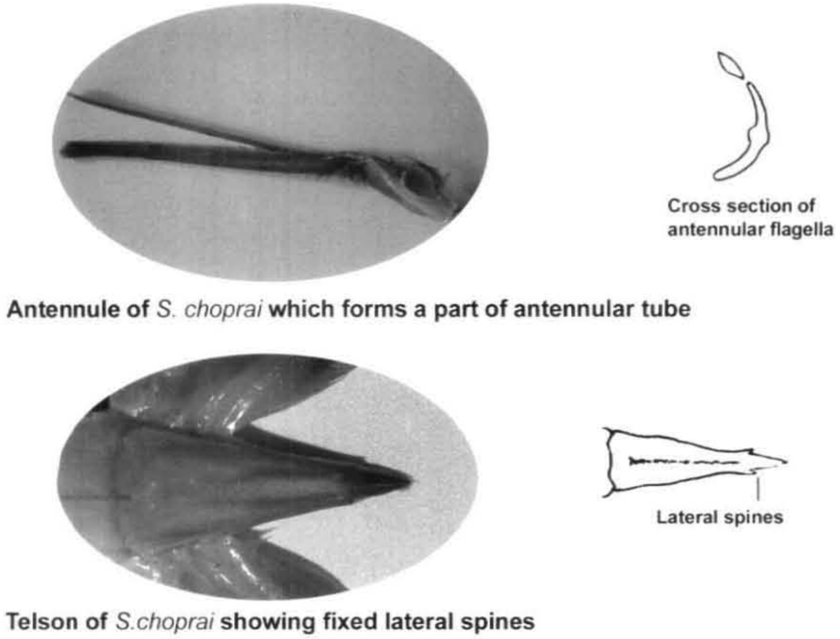
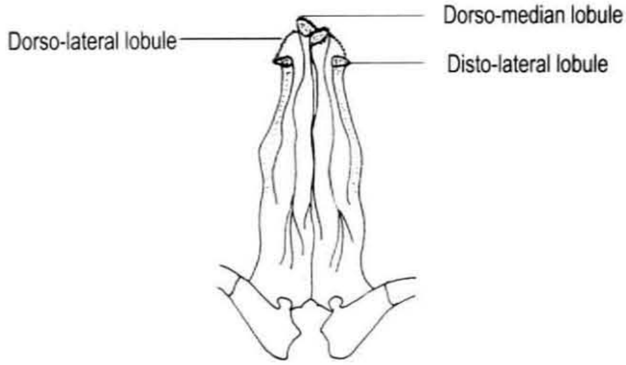
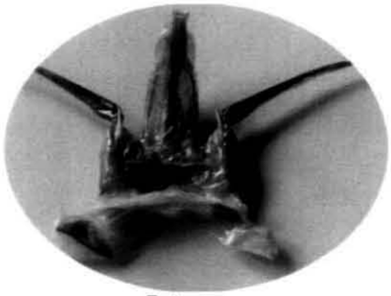


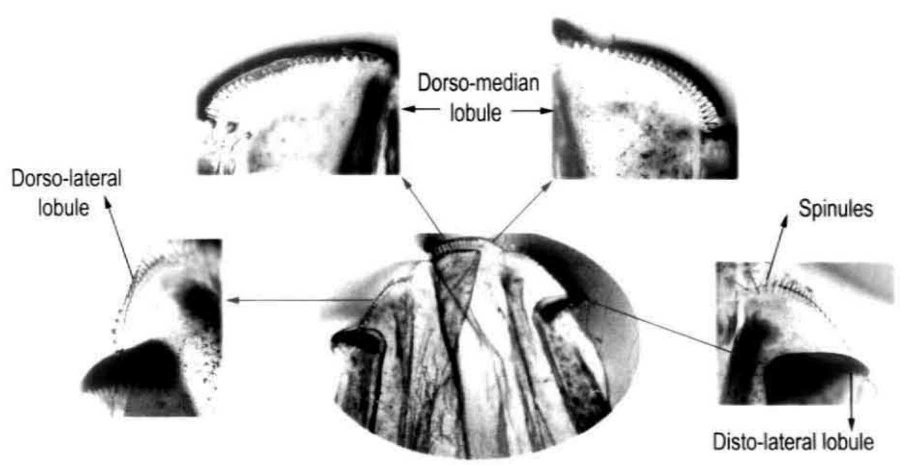
Fig. 2.3. Diagnostic features of antennule and telson of *S. choprai*.



Diagramatic representation of structure of petasma

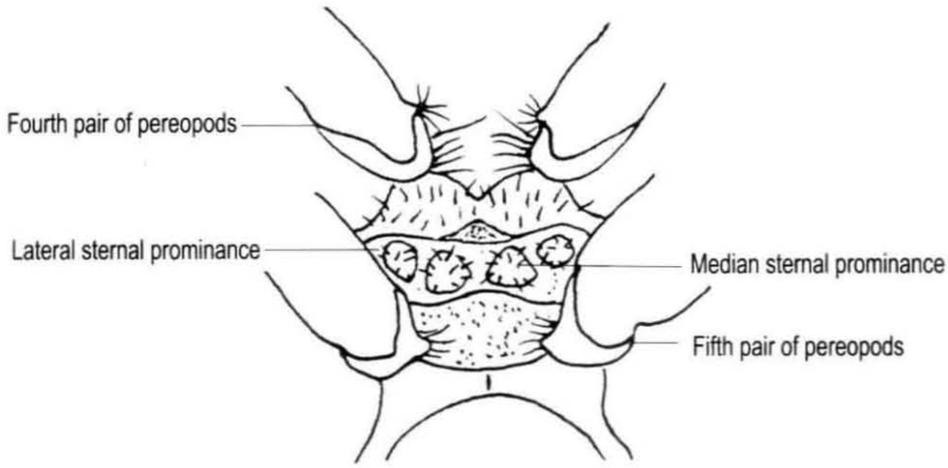


Petasma

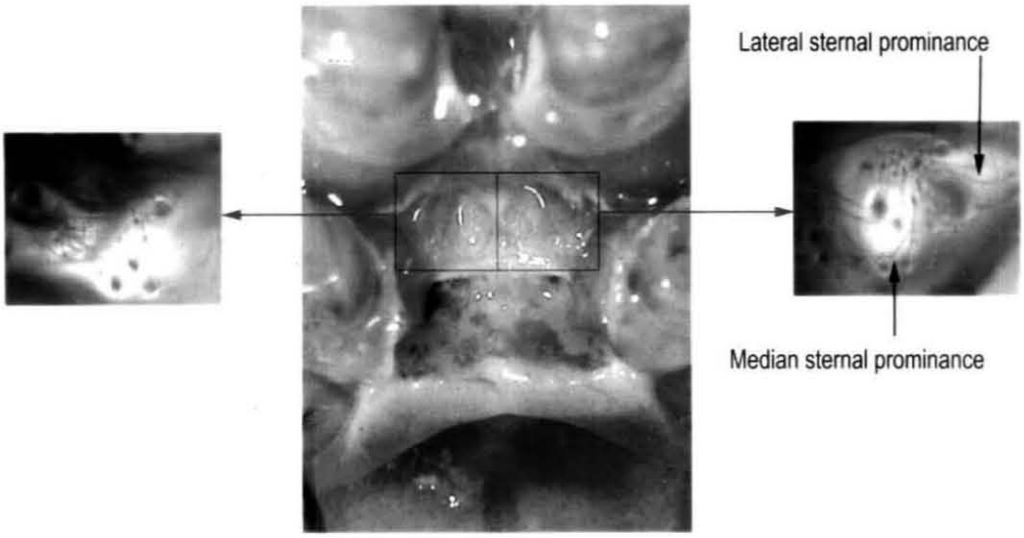


Petasma showing diagnostic features of the species

Fig. 2. 4. Diagnostic features of the external reproductive structures of males of *S. choprai*.



Diagramatic representation of structure of thelycum



Thelycum showing diagnostic features of the species

Fig. 2. 5. Diagnostic features of the external reproductive structures of females of *S. choprai*.

4.3. Length-weight Relationship

4.3. LENGTH-WEIGHT RELATIONSHIP

4.3.1. RESULTS

4.3.1.1. Total length-total weight relationship

A total of 347 males ranging in length from 5.3 to 9.4 cm and 365 females ranging in total length from 7.5 to 11.3 cm were used to study the total length-weight relationship of *S. choprai*. The raw sums of squares and product of log total length and log total weight for males and females are shown in Table 3.1. The regression equations between male and female were tested for equality through analysis of covariance (ANACOVA). Table 3.2 shows that the values of slope and elevation differ significantly at 1% level. However, as it is a prerequisite in stock assessment studies, a common equation for the species was found out after pooling the data of males and females.

The regression equations for the length-weight relationship of males (n = 347), females (n = 365) and pooled (n = 712) were calculated as under:

Males : $\text{Log}\ W = -4.72466 + 3.18531\ \text{Log}\ L$ (r = 0.985448)

Females : $\text{Log}\ W = -3.79389 + 2.76114\ \text{Log}\ L$ (r = 0.984467)

Pooled : $\text{Log}\ W = -4.47784 + 3.06821\ \text{Log}\ L$ (r = 0.989455)

Where W is the total weight (in g) and L the total length (in cm). The calculated curves of total length-total weight relationship for males and females are shown in figures 3.1, 3.2, 3.3 and 3.4.

The length-weight relationship for males, females and sexes pooled in the form $W=aL^b$ is as follows:

Males : $W = 0.008874\ L^{3.18531}$

Females : $W = 0.022507\ L^{2.76114}$

Pooled : $W = 0.011357\ L^{3.06821}$

The '*t* test' was conducted to test the isometric growth in *S. choprai*. The value of *t* calculated was 1.0901 (sex pooled data), which did not show any significant difference at 5% level from the expected value of 3, indicating isometric growth in the species.

4.3.1.2. Carapace length-weight relationship

The data on the carapace length and total weight of the shrimps were also analysed using the formula used for the total length-total weight relationship (Figs. 3.5, 3.6, 3.7 and 3.8).

The regression equation between male and female was tested for equality through analysis of covariance (Table 3.3). Table 3.4 shows that the values of slope and elevation differ significantly at 1% level.

The regression equations for the carapace length-weight relationship for males, females and pooled were calculated as under:

Males : $\text{Log } W = 0.17814 + 2.260825 \text{ Log } CL$ (r = 0.980195)

Females : $\text{Log } W = 0.41105 + 2.005492 \text{ Log } CL$ (r = 0.977403)

Pooled : $\text{Log } W = 0.23471 + 2.18830 \text{ Log } CL$ (r = 0.986651)

The length-weight relationship for males, females and sexes pooled in the form $W = aL^b$ is as follows:

Males : $W = 1.194996\ CL^{2.260825}$

Females : $W = 1.508412\ CL^{2.005492}$

Pooled : $W = 1.264542\ CL^{2.18830}$

4.3.1.3. Total length-carapace length relationship

A preliminary plot of the total length and carapace length indicated that separate estimates were needed for males and females (Fig. 3.9 and 3.10). The regression equations between male and female were tested for equality through analysis of covariance (Table 3.5). Table 3.6 shows that the values of slope and elevation differ significantly at 1% level. The equation for total length-carapace length relationship for males and females and the pooled data are as follows:

The regression equations for the total length-carapace length relationship of males (n = 347), females (n = 365) and pooled (n = 712) were calculated as under:

Males : $TL = 21.6895 + 2.718222\ CL$ (r = 0.995892)

$CL = -7.75017 + 0.364871\ TL$

Females : $TL = 23.88158 + 2.605482\ CL$ (r = 0.995209)

$CL = -8.83451 + 0.380137\ TL$

Pooled : $TL = 23.31913 + 2.63141\ CL$ (r = 0.997055)

$CL = -8.67563 + 0.37779\ TL$

4.3.2. DISCUSSION

This is the first report of its kind on length-weight relationship of *S. choprai*. Length-weight relationship of species belonging to *Solenocera* genus, *S. crassicornis* was studied by Sukumaran (1978) in Indian waters. He observed that males and females require different equations for length-weight relationship and the '*b*' values varied widely in males and females *viz.*, 2.86 and 3.12 respectively. Kunju (1968) studied the carapace length–total length relationship and a general formula, $TL = 6.19 + 3.20\ CL$ was found suitable for both males and females. Ohtomi and Irieda (1997), who studied the length- weight relationship of *S. melantho,* which is similar to *S. choprai* in morphology and depth of distribution, found significant difference in slopes and elevation in the regression graph for length-weight relationship for males and females. The estimated '*b*' values were 2.95 and 2.71 for males and females respectively. Males had relatively more body weight than females of similar size. Baelde (1994) studied the carapace length-weight relation of *Haliporoides sibogae*, a deep water shrimp belonging to Solenoceridae family. In this study also he found wide difference of '*b*' values for males and females, 2.89 and 2.51 respectively, males being heavier than females of similar size. Present study revealed that in *S. choprai* also males had higher *b* values than females. Similar higher '*b*' values for males were reported by Ivanov and Krylov (1980) in green shrimp, *Penaeus latisulcatus*, and deep water shrimps *Penaeopsis balssi, Parapenaeus sextuberculatus* and *Aristaemorpha foliacea* from Indian Ocean.

Rao (1988) comparing the total length and the carapace length of *M. monoceros* stressed the need for separate equations to define relationship for juveniles, adult males and females. Ivanov and Krylov (1980) also have found that it requires separate equations to explain carapace length-total length relationship of males and females in all the nine shrimp species, they studied from the western Indian Ocean. In the present study also, it required separate equation for males and females and the variation was found statistically significant.

Table 3.1. Results of the total length–total weight analyses of males and females of *S. choprai* and their pooled value.

Transformation applied: Log (*Y*) = a + b * Log (*X*)

Group	N	Mean X	Mean Y	*a*	*b*	r
Male	347	2.021	1.712	0.008874	3.18531	0.985448
Female	365	2.196	2.269	0.022507709	2.76114	0.984467
Pooled	712	2.111	1.998	0.011357875	3.06821	0.989455

Table 3.2. Comparison of the regression lines of the total length–total weight relationship of *S. choprai.*

Corrected sum of squares and products					Regression coefficient	Deviation from regression			
SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	346	4.5754	14.5742	47.8045	3.185	345	1.381	0.00400	
Female	364	3.7598	10.3814	29.5762	2.761	363	0.912	0.00251	
Total						708	2.293	0.00324	
Pooled within	710	8.3352	24.9556	77.3807	2.994	709	2.664	0.00376	
Difference between slopes						1	0.371	0.37132	**114.66**
Between sexes	1	5.4483	17.3354	55.157					
TOTAL	711	13.7836	42.2910	132.5383	3.068	710	2.780	0.00392	
Difference between corrected means						1	0.116	0.11620	**30.92**

Comparison of slopes: F = 114.66 (*df,* 1and 709), significant at 1% level .
Comparison of elevation: F = 30.92 (*df,* 1and 710), significant at 1% level.

Table 3.3. Results of the carapace length-total weight relationship analyses of males and females of *S. choprai* and their pooled value.

Transformation applied: Log (Y) = a + b * Log (X)

Sex	N	Mean X	Mean Y	a	b	r
Male	365	0.679	1.712	0.17814	2.26083	0.980195
Female	347	0.926	2.269	0.41106	2.00549	0.977403
Pooled	712	0.806	1.998	0.23471	2.18830	0.986651

Table 3.4. Comparison of the regression lines of the carapace length-total weight relationship of *S. choprai.*

Corrected sum of squares and products					Regression coefficient	Deviation from regression			
SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	346	8.9859	20.315	47.8045	2.261	345	1.875	0.00543	
Female	364	7.0250	14.088	29.5762	2.005	363	1.322	0.00364	
Total						708	3.196	0.00451	
Pooled within	710	16.0109	34.4041	77.3807	2.149	709	3.453	0.00487	
Difference between slopes						1	0.257	0.25704	**56.94**
Between sexes	1	10.9327	24.5565	55.157					
TOTAL	711	10.9327	58.9606	132.5383	5383 2.	710	3.515	0.00495	
Difference between corrected means						1	0.062	0.06158	**12.64**

Comparison of slopes: F = 56.99 (*df*, 1 and 709), significant at 1% level.
Comparison of elevation: F = 12.64 (*df*, 1and 710), significant at 1% level.

Table 3.5. Results of the carapace length-total length relationship analyses of males and females of *S. choprai* and their pooled value.

Transformation applied: $Y = a + b X$

Sex	N	Mean X	Mean Y	a	b	r
Male	365	19.967	75.965	21.68950	2.71822	0.995892
Female	347	25.499	90.318	23.88158	2.60548	0.995209
Pooled	712	22.803	83.323	23.31913	2.63141	0.997055

Table 3.6. Comparison of the regression lines of the carapace length-total length relationship of *S. choprai.*

Corrected sum of squares and products					Regression coefficient	Deviation from regression			
SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	346	3651.5820	9925.8092	27203.5850	2.718	345	223.036	0.64648	
Female	364	4543.7493	11838.6589	31143.1342	2.605	363	297.717	0.82016	
Total						708	520.752	0.73553	
Pooled within	710	8195.3313	21764.4681	58346.7193	2.656	709	546.485	0.77078	
Difference between slopes						1	25.732	25.73232	**34.98**
Between sexes	1	5442.2725	14121.6535	36642.9830					
TOTAL	711	13637.6038	35886.1216	94989.7022	2.631	710	558.617	0.78678	
Difference between corrected means						1	12.132	12.13238	**15.74**

Comparison of slopes: F = 34.98 (*df*, 1and 709), significant at 1% level.
Comparison of elevation: F =15.74 (*df*, 1and 710), significant at 1% level.

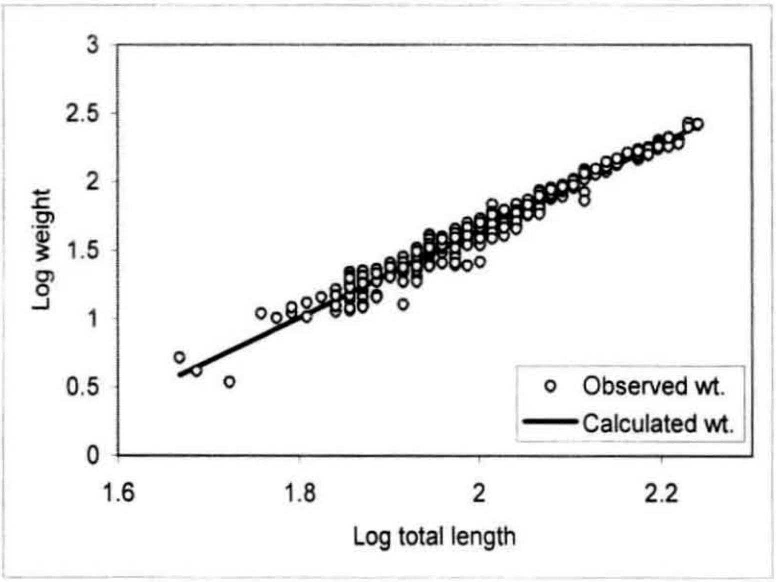


Fig. 3.1. Logarithmic relationship between total length and weight in males of *S. choprai.*

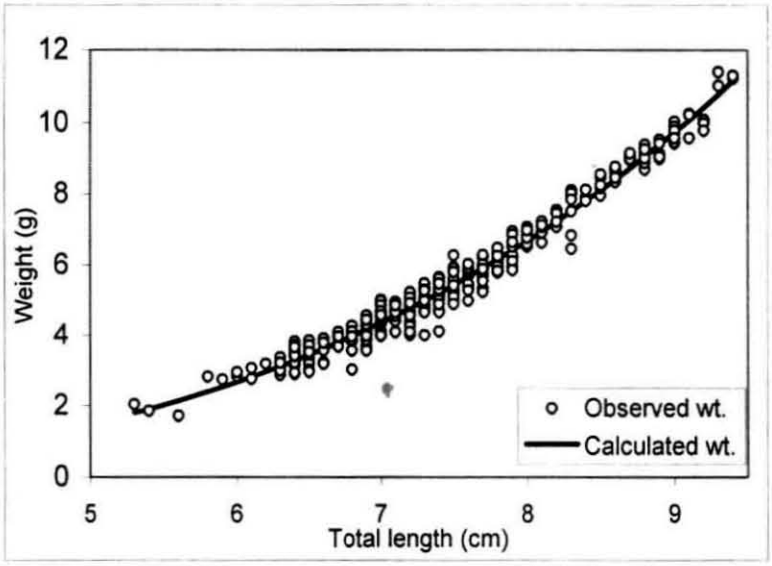


Fig. 3.2. Relationship between total length and weight in males of *S. choprai.*

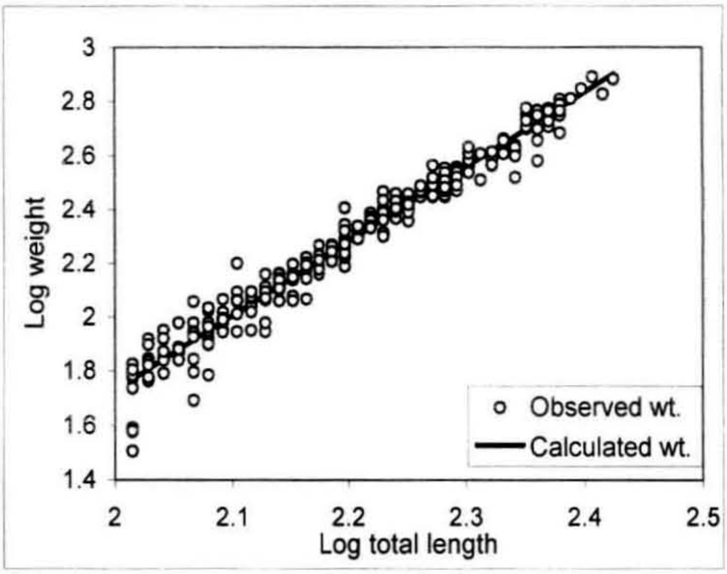


Fig. 3.3. Logarithmic relationship between total length and weight in females of *S. choprai.*

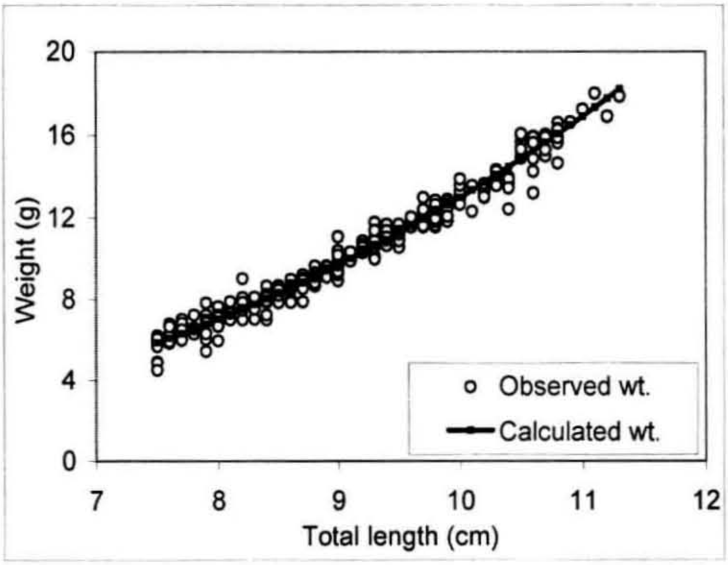


Fig. 3.4. Relationship between total length and total weight in females of *S. choprai.*

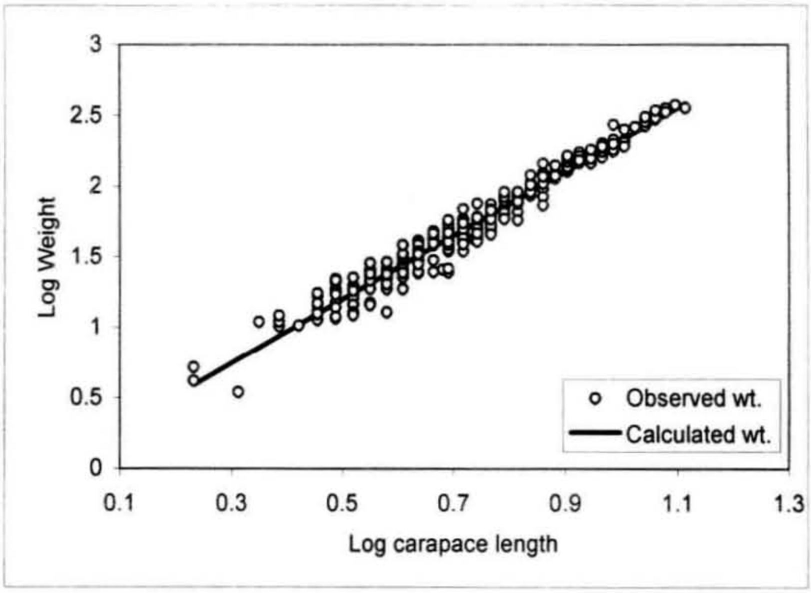


Fig. 3.5. Logarithmic relationship between carapace length and total weight in males of *S. choprai.*

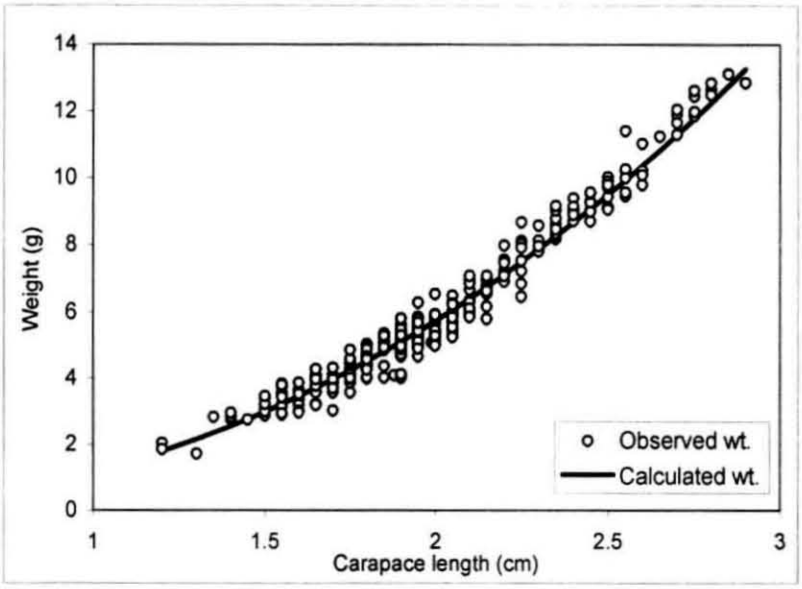


Fig. 3.6. Relationship between carapace length and total weight in males of *S. choprai.*

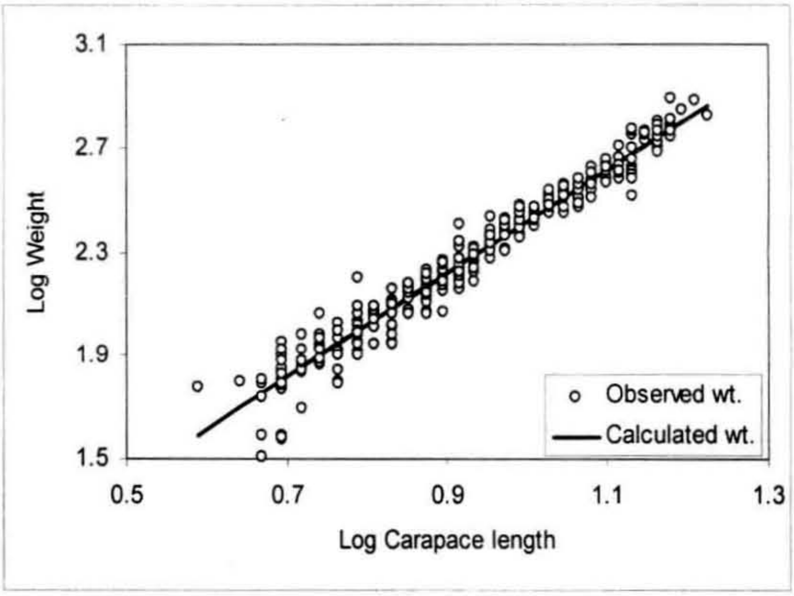


Fig. 3.7. Logarithmic relationship between carapace length and weight in females of *S. choprai.*

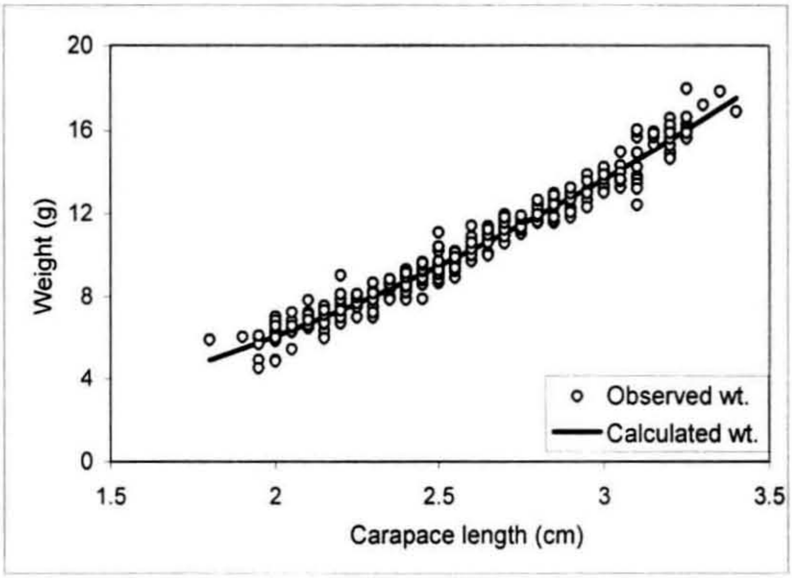


Fig. 3.8. Relationship between carapace length and total weight in females of *S. choprai.*

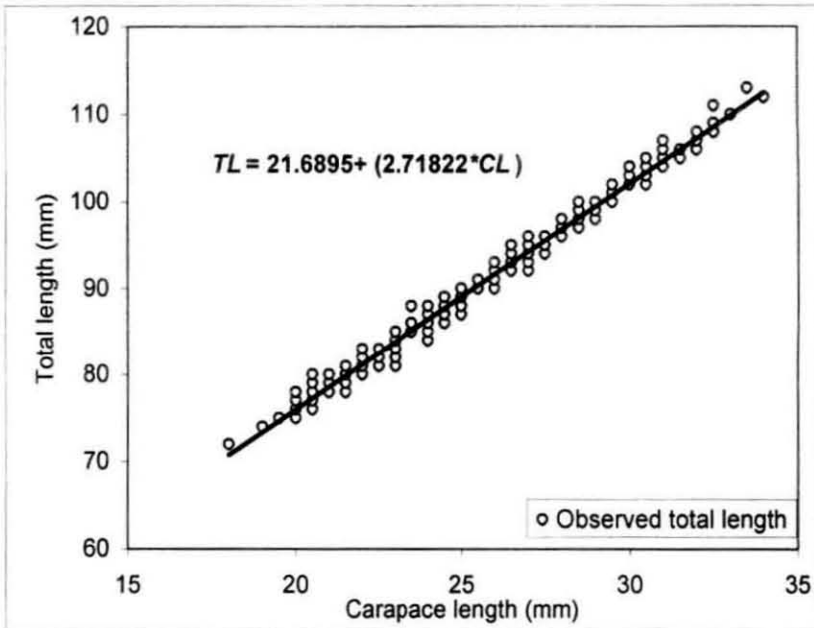


Fig. 3.9. Relationship between carapace length and total length in males of *S. choprai.*

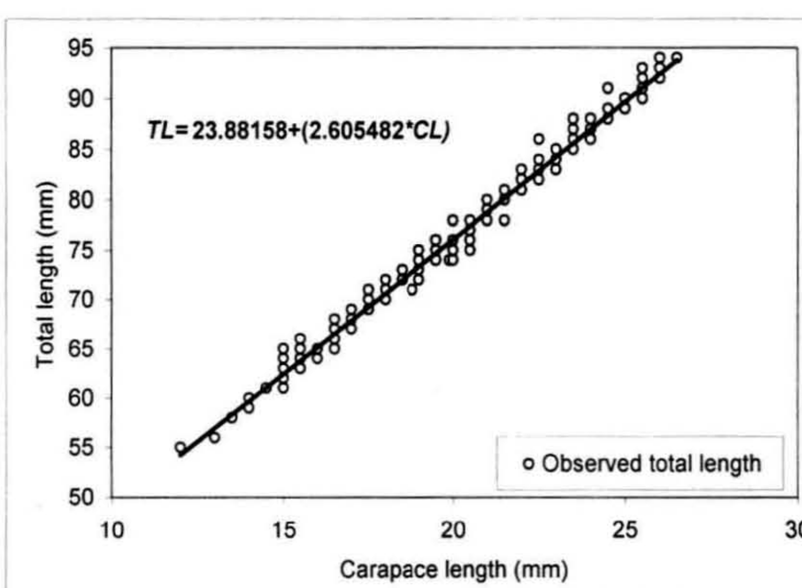


Fig. 3.10. Relationship between carapace length and total length in females of *S. choprai.*

4.4. Food and Feeding

4.4. FOOD AND FEEDING

4.4.1. RESULTS

4.4.1.1. General diet composition of *S. choprai*.

The diet composition in adults and juveniles of *S. choprai* is given in Figs. 4.1 to 4.4. The food contents found in adult *S. choprai*, in the order of abundance were, decapod crustaceans, digested mass and detritus, 'fish remains', molluscan shells, polychaete worms, sand, foraminiferans and small crustaceans (other than decapods). The index of preponderance (hereafter referred as index) for each food item is given in Table 4.1.

Decapod crustaceans, dominated by shrimps formed the major component in the stomach content of *S. choprai*. The annual index for decapod crustaceans was 43.82. The index was as high as 59.13 in March. The index was more than 30 in all months except June. During February and September juvenile crabs dominated the food items and in other months, shrimps were dominant.

Digested mass and detritus consisting of decomposed plant and animal matter and their remains mixed with mud ranked second among the food items with an annual index of 19.27. Maximum concentration of detritus was during the monsoon months and also immediately after monsoon. Detritus was the major component during June and till September with an index > 20.

'Fish remains' constituted the third important component with an index of 11.17. This component ranked first in June and from June to September ranked second with an index of more than 20. Fish bones, spines, scales and fish eggs were identified from the stomach. Fish eggs were found in notable quantity from March to June.

Molluscan shells were present throughout the year and ranked fourth with an index value of 8.15. Maximum concentration of molluscan shells was present during January-February. Crushed shells of various bivalves, gastropods and intact tusk shells were observed in the stomach. Fresh appearance of shells as well as partly digested flesh indicated that the molluscans were consumed alive.

Polychaete worms were recorded in the stomach only in January and April. This component ranked fifth among the food components with an index of 7.16. During May, August and October, polychaetes were completely absent in the stomach contents.

Sand was found invariably in all stomachs and ranked sixth with an index of 5.24. The index of sand was the highest (9.28) in June. This item was probably an accidental inclusion while the shrimp was feeding at the bottom.

Along with sand, foraminiferan shells were also found in good quantity throughout the year, with an index of 3.27. *Spiroplecta, Rotalia, Elphidium* and *Globigerina* were the important foraminiferans identified. From May to September the index of foraminiferans were low compared to other months.

Small crustaceans other than decapods constituting amhipods, *Cypris* and *Lepas* larvae formed a minor component in the food content with an overall index of 1.92. *Lepas* larvae were found in the stomach content from February to June. *Cypris* was present throughout the year.

4.4.1.2. Monthly variation in the percentage composition of diet

The monthly variation of diet composition in adults is given in Table 4.1. Decapod crustaceans were the major constituent of the food throughout the year except in June. In June 'fish remains' were the major component. In monsoon months, from June to August good quantity of detritus was found in the stomach than in other months. Statistical analysis of variance of food content with months showed significance at 1% level (Table 4.2).

4.4.1.3. Diet composition of juveniles

The diet composition of juveniles and adults of *S. choprai* is presented in Figs. 4.3 and 4.4. Adults of *S. choprai* were available throughout the trawling period in 2003, while juveniles were observed in good quantity in November. A few numbers of juveniles were collected during January also but were in spoiled condition. The food and feeding studies on juveniles were conducted only during November. Unlike adults, 'fish remains' were the major component of food item in juveniles during this month with an index of 38.1. In adults the dominant food component during this month was decapod crustaceans with an index of 47.31. Detritus was found in comparatively less percentage in juveniles than adults. Foraminiferans, sand and molluscan shells showed higher index. Polychaete worms were not seen in the stomach content of juveniles (Table 4.3). The statistical analysis of variance in food component between adults and juveniles showed that the variation of 'fish remains', foraminiferans, molluscan shells and polychaetes were significant at 1% level and small crustaceans were significant at 5% level (Table 4.4).

4.4.1. 4. Diet composition in males and females

The diet composition in males and females of *S. choprai* is given in Figs. 4.1 and 4.2 (Tables 4.5 and 4.6). It is seen that there is no marked difference between the diet composition of males and females. In both cases, decapod crustaceans were the major component with indices of 43.49 and 44.04 in males and females respectively. Polychaete worms recorded higher index in females than males particularly during January and April. Analysis of variance in food component between males and female did not show significance at 1% level (Table 4.7).

4.4.1.5. Diet composition in relation to size

4.4.1.5.1. Diet composition in relation to size in males

Diet composition in different size classes of males of *S. choprai* is given in Table 4.8. The specimens were classified into six size classes with a class interval of 5 mm *viz.* those below 65 mm, 66-70 mm, 71-75 mm, 76-80 mm, 81-85 mm and above 85 mm. Decapods were the major component in the diet of shrimps of all length ranges. From 66 to 85 mm, the index of decapod crustaceans was above 40, whereas in the lower and upper size ranges, the index was comparatively low. In shrimps of 71 to 85 mm 'fish remains' had an index value of > 12 whereas in lower and higher size-classes the index was below 10. In males > 85mm, the index for polychaete worms was the highest and the indices for molluscan shells, foraminiferans and sand were the lowest (Table 4.8). Analysis of variance of food content in different size groups of males did not show any significant difference at 1% level (Table 4.9).

4.4.1.5.2. Diet composition in relation to size in females

In females eight size classes were differentiated as those below 70 mm, 71-75 mm, 76-80 mm, 81-85 mm, 86-90 mm, 91-95 mm, and 96-100 mm and those above 100 mm. In females also decapod crustaceans were the major diet component in all size groups (Table 4.10). The index was highest (61.11) in lower sized shrimps i.e., below 70 mm. Sand and foraminiferans showed highest index in the lowest size-class shrimps and lowest index in the highest size-class shrimps. In the case of 'fish remains' the trend was opposite with smallest index seen in smallest size class and highest index seen in the highest size class, thus indicating a change in feeding behaviour in different size classes (Table 4.10). Analysis of variance of food content with different size group of females showed significance at 1% level, except for 'fish remains' and sand (Table 4.11).

4.4.1.6. Diet composition in relation to maturity stages in females

Diet composition in difference maturity stages (immature, early maturing, late maturing, mature and spent) of females of *S. choprai* is given in Table 4.12. In all the maturity stages the major component of the food was decapod crustaceans with indices above 40. Highest index of decapod crustaceans was observed in mature females (65.36). 'Fish remains' showed lowest index in immature females (4.74), whereas in all other stages the index was above 10. Analysis of variance of small crustaceans and detritus with maturity stages of females showed significance at 1% level, and that of decapod crustaceans at 5% level (Table 4.13).

4.4.1.7. Feeding intensity

The intensity of feeding was determined by the degree of distension of the proventriculus due to the quantity of food inside the anterior and posterior chambers. Feeding condition is expressed as actively fed, moderately fed and poorly fed. Shrimps with full and ¾ full stomachs were considered as actively fed, shrimps with ½ full and ¼ full stomachs were considered as moderately fed and shrimps with less than ¼ full stomach is considered as poorly fed (Table 4.14). Analysis of variance of stomach fullness with sex showed significance at 5% level (Table 4.7).

4.4.1.7.1. Feeding intensity in adults

Feeding intensity of the adult *S. choprai* during the period of study was 28.88%. The highest feeding intensity was observed in February (54%). From

February to March feeding intensity was more than 49%. From June onwards the feeding intensity dropped and was less than 15% till November. During November and December shrimps showed increased feeding intensity (Fig. 4.5). In February actively fed (37%) and moderately fed (47%) females were more than those in other months (Table 4.14). From May to October poorly fed shrimps were more than 70%. Actively fed shrimps were not seen in October.

4.4.1.7.2. Feeding intensity in juveniles

Feeding intensity of the juveniles was 42% (Table 4.15), 26% of the juveniles were actively fed and 41% were moderately fed (Fig. 4.6). Analysis of variance of fullness of stomach between juveniles and adults showed significance at 5% level (Table 4.4).

4.4.1.7.3. Feeding intensity in males

4.4.1.7.3.1. Feeding intensity in relation to months

In males, the annual feeding intensity for the year was 26% with the highest during February-April. Lowest feeding intensity of 4% was observed in May and this trend continued till October. During November-December the intensity of feeding increased slightly (Table 4.16). The feeding condition in males of *S. choprai* is given in Fig. 4.7. Actively fed males were more in April (40%). Moderately fed males were more in February (60%). From May to October, majority of the males were poorly fed (69-90%). During May, June, August and October not a single actively fed male was observed.

4.4.1.7.3.2. Feeding intensity in relation to size

Feeding intensity was the highest in shrimps in the 81-85 mm size class (43.82%) (Table 4.17) and did not show any relation with respect to size (Fig. 4.8). Actively fed males were also found maximum in the 81-85 mm size group. Specimens below 65 mm and in 76-80 mm size class, the percentage of poorly fed was above 60.

4.4.1.7.4. Feeding intensity in females

4.4.1.7.4.1. Feeding intensity in relation to months

In females annual feeding intensity for the year 2003 was 31.57%. Highest feeding intensity was observed during February (54.46%) (Fig. 4.5). During this month 39.29% shrimps were actively fed and 42.86% were moderately fed. In May and October the feeding intensity was below 10% and poorly fed females were more than 80% (Fig. 4.9). In October actively fed shrimp was not recorded (Table 4.18).

4.4.1.7.4.2. Feeding intensity in relation to size

Feeding intensity was highest (45.00%) in shrimps having a total length of more than 100 mm (Table 4.19). Direct or inverse relationships of feeding intensity with size groups were not noticed during the study (Fig. 4.10). More than 50% of females belonging to 96-100 mm size class were poorly fed.

4.4.1.7.4.3. Feeding intensity in relation to maturity stages

Feeding intensity was highest in immature females (40.71%). Spent females showed higher feeding intensity than the maturing ones (Table 4.20). Among immature shrimps, 21.43% were actively fed and 57.14% were moderately fed. More than 50% of early maturing, late maturing and mature females were poorly fed (Fig. 4.11). Analysis of variance of fullness of stomach with different maturity stages of females showed significance at 5 % level (Table 4.13).

4.4.2. DISCUSSION

Reports on the food and feeding habits of *S. choprai* are not available from any part of the world except from the studies conducted by Aravindakshan and Karbari (1994) form Bombay waters. The studies were conducted on *S. choprai* collected from 40-70 m depth during 1977-1986 and found that crustaceans formed 50% of the food component, followed by polychaetes (15%) and foraminiferans and molluscs together formed (10%). Sand grains and debris formed 25% of the gut content. During the present study also crustaceans were found to be the major component with a preponderance index of 46 (43 for decapod crustaceans and 3 for smaller crustaceans). Molluscan shells and foraminiferans were found throughout the study period with an annual preponderance index of 11. Polychaete worms were less in concentration compared with the result of the studies by Aravindakshan and Karbari (1994). However 'fish remains' formed one of the major constituent of the stomach content with an annual index of 11. Sand and detritus formed one fourth of the stomach content as reported by Aravindakshan and Karbari (1994). Due to intensive fishing activity at depths beyond 50 m, this area received a lot of discarded fishes from trawlers. The presence of 'fish remains' in the stomach of *S. choprai*, in the present observation can be attributed to this. Similar observations were reported by Saint-Marie and Chabot (2002) in American lobsters, *Homarus americanus*, in which those caught from the areas of trawl discards were found to have more 'fish remains' in the stomach content than those caught from the fishing grounds which is having no trawl discards. Kunju (1968), while conducting studies on *Solenocera indica* from Bombay waters at depth of 20 to 30 m, found that major part of the gut content of *S. indica* was composed of food from crustacean origin (44.69%), mainly of decapods. He also reported substantially good quantity of 'fish remains' (22.12%) in the stomach content.

Tiews *et al.*, (1968) while studying the food and feeding habits of four shrimps, *P. semisulcatus, P. canaliculatus, P. merguiensis* and *M. monoceros* in two different ecosystems in Philippine waters found that diet composition of shrimps was related to the availability of food items than their selective feeding. They also reported considerable amount of foraminiferans in the gut content of shrimps caught offshore than in the near shore waters. Hashimi *et al.* (1978), Harkantra *et al.* (1980), Kidwai *et al.* (1981) and Shankar and Karbassi (1992) found that there is a patch of sandy region off South

Karnataka extending from a depth of 50 to 200 m which is not seen anywhere in the west coast of India. The fishing ground of *S. choprai* also falls within this region (60 to 100 m). Hashimi *et al.* (1978) during his studies on benthic population of this area found that 70% of the coarse fraction is formed by foraminiferan shells. High concentration of foraminiferans in the substratum may be the reason for consistent presence of good quantity of foraminiferan shells in the gut content of *S. choprai.*

The high incidence of crustacean parts and 'fish remains' indicate the carnivorous habit of *S. choprai*. Kishinouye (1900), Ikematsu (1955), Kubo (1956), Yasuda (1956), Hall (1962), Subramanyam (1967), Thomas (1972), George (1974), Mohanthy (1975) and Marte (1980) also stated that shrimps in adult form have carnivorous food habit. Marte (1980) observed that *P. monodon* in Philippine waters is less of a scavenging and more of a predator of slow moving micro invertebrates, mainly small crabs and molluscs. Hall (1956) during the study on food habits of *S. subnuda* and *S. alticarinata* observed that the habit of the species was more predatory with specific food preference. Presence of flesh in the crushed molluscan shells found in the stomach content of *S. choprai* also give an indication of its predatory habit, but the evidence is not very conclusive.

The monthly variation of gut content showed significance. Decapod crustaceans were having indices of 59.3 and 51.57 during March and May respectively, whereas 'fish remains' showed high index of preponderance during May to August. Sharma (1978) found that the upwelling in southwest coast of India starts in deeper waters from May onwards leading to a total churning of the sea bottom and this disturbance will cease by September. The non-availability of preferred food items like decapod crustaceans during the period of churning may be a reason for the observed change in food consumption. During the monsoon months gut contents showed more percentage of detritus. Tiews *et al.* (1968) also described similar changes in food preference of shrimps according to food availability during various seasons in Philippine waters.

There was significant variation of food preference between adult and juvenile in the case of polychaetes, 'fish remains' and smaller crustaceans. Differences in the composition of food content of juveniles and adults were reported by Subramanyam (1973), Rao (1988b), Cartes and Sarda (1989) and Nandakumar (1997). Keast (1978) stated that the difference in food preference of juveniles and adults of species having extended breeding season is a natural mechanism to reduce intra specific competition of food between them, so as to ensure better survival of the species.

No significant variation of food preference between males and females and between the size-classes of adult shrimps was observed in the present study. Cartes and Sarda (1989) also derived similar conclusions while studying the food and feeding habits of *Aristaeus antennatus*. In the present study, food preference of females of *S. choprai* in different maturity stages showed significant variation, especially in the case of crustaceans as food, with mature females preferring more than other stages. Similar findings were reported by Scarrat (1980) in lobsters. He found they consumed more crabs, mussel and fish but fewer echinoderms as they approach maturity.

Feeding intensity of the adults showed wide fluctuations during the period of study. Feeding intensity was highest during January-April and was very low during May-October. From November onwards feeding intensity increased again (30 to 32%). The low feeding intensity during May-October can be attributed to the disturbance and instability of the bottom waters due to upwelling (Sharma, 1978) resulting in the scarcity of preferred food items. During November, when the juveniles were found in good quantity, the feeding intensity of juveniles was 26% whereas the same for the adults was 19%. Similar observations were also reported by Rao (1988b) and Nandakumar (1997) in *M. monoceros* and Thomas (1980) in *P. semisulcatus*.

By habit *S. choprai* is a burrowing species with antennules forming a respiratory tube for breathing while burrowing (Chan, 1998). Analysis of the catch data recorded during day and night trawl operations revealed that the fishery was successful only during night time, which suggests that the activities of *S. choprai* including feeding are more during night than day. Eldred *et al.* (1961), while studying the habits of *P. duorarum* inferred that most of the shrimps which are having a burrowing habit have a nocturnal feeding habit.

Table 4.1. Month-wise 'index of preponderance' of food items of *S. choprai* (adults).

Month	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminifer-an shells	Sand	Detritus	No. of shrimps
Jan	1.72	34.41	11.20	7.47	12.42	3.60	5.63	23.55	65
Feb	2.22	39.10	4.57	17.59	11.27	4.76	4.86	15.62	38
Mar	2.03	59.13	3.54	9.51	4.95	2.05	2.96	15.84	40
Apr	1.07	46.10	10.78	7.65	6.71	2.88	4.81	20.01	80
May	2.22	51.57	0.00	22.69	1.91	1.09	2.93	17.59	40
Jun	0.27	9.19	6.31	35.95	2.04	1.59	9.28	35.39	40
Aug	1.20	32.10	0.00	26.95	3.70	1.35	4.55	30.15	36
Sep	1.53	44.48	5.81	11.10	4.86	1.77	3.19	27.26	70
Oct	1.17	50.68	0.00	16.82	8.31	2.48	5.48	15.06	60
Nov	2.57	47.31	7.70	11.53	7.07	3.75	5.56	14.51	129
Dec	2.82	48.17	4.05	7.70	8.96	3.88	6.71	17.71	101
ANNUAL	1.92	43.82	7.16	11.17	8.15	3.27	5.24	19.27	699

Table 4.2. Results of statistical analysis of variance of food items with different months.

Food Item with month		**SS**	**Df**	**mS**	**F**	**Sig.**
Decapod crustaceans	Between Groups	41054.01	10	4105.40		
	Within Groups	251653.84	688	365.78	11.22	**<0.01**
	Total	292707.86	698			
Digested matter	Between Groups	4620.89	10	462.09		
	Within Groups	37548.21	688	54.58	8.47	**<0.01**
	Total	42169.10	698			
Foraminiferans	Between Groups	272.65	10	27.27		
	Within Groups	1129.90	688	1.64	16.60	**<0.01**
	Total	1402.55	698			
Fish remains	Between Groups	2373.74	10	237.37		
	Within Groups	46689.08	688	67.86	3.50	**<0.01**
	Total	49062.82	698			
Polychaetes	Between Groups	2041.99	10	204.20		
	Within Groups	50358.83	688	73.20	2.79	**<0.01**
	Total	52400.81	698			
Small crustaceans	Between Groups	84.14	10	8.41		
	Within Groups	1696.21	688	2.47	3.41	**<0.01**
	Total	1780.35	698			
Sand	Between Groups	384.01	10	38.40		
	Within Groups	2696.58	688	3.92	9.80	**<0.01**
	Total	3080.59	698			
Molluscan shells	Between Groups	1595.05	10	159.50		
	Within Groups	7915.99	688	11.51	13.86	**<0.01**
	Total	9511.04	698			
Stomach fullness	Between Groups	153711.71	10	15371.17		
	Within Groups	590267.90	688	857.95	17.92	**<0.01**
	Total	743979.61	698			

SS = sum of squares; **Df** = Degrees of freedom; **mS** = mean square; **F** = F value; **Sig** = significance levels.

Table 4.3. 'Index of preponderance' of food items in the juveniles of *S. choprai.*

Month	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminifer-an shells	Sand	Detritus	No. of shrimps
Nov, 2003	0.93	26.19	0	38.1	13.2	5.23	8.34	8.01	100

Table 4.4. Results of statistical analysis of variance of food items in juveniles and adults.

Food item with adults and juveniles		SS	Df	mS	F	Sig.
Decapod crustaceans	Between Groups	1033	1	1033.15	1.78	NS*
	Within Groups	131601	227	579.74		
	Total	132634	228			
Digested matter	Between Groups	99	1	98.78	2.02	NS
	Within Groups	11106	227	48.93		
	Total	11205	228			
Foraminiferans	Between Groups	55	1	54.75	13.68	<0.01
	Within Groups	909	227	4.00		
	Total	963	228			
Fish remains	Between Groups	8533	1	8532.77	31.59	<0.01
	Within Groups	61316	227	270.12		
	Total	69849	228			
Polychaetes	Between Groups	602	1	602.09	18.54	<0.01
	Within Groups	7371	227	32.47		
	Total	7974	228			
Small crustaceans	Between Groups	350	1	349.89	6.64	<0.05
	Within Groups	11962	227	52.70		
	Total	12312	228			
Sand	Between Groups	11	1	10.85	3.55	NS
	Within Groups	693	227	3.05		
	Total	704	228			
Molluscan shells	Between Groups	165	1	164.91	12.55	<0.01
	Within Groups	2983	227	13.14		
	Total	3148	228			
Stomach fullness	Between Groups	5255	1	5254.62	4.17	<0.05
	Within Groups	286065	227	1260.20		
	Total	291319	228			

***NS** = not significant

Table 4.5. Month-wise 'index of preponderance' of food items in males of *S. choprai.*

Month	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminiferan shells	Sand	Detritus	No. of shrimps
Jan	1.86	29.87	2.65	9.60	18.14	5.31	9.56	23.01	29
Feb	0.00	43.63	1.96	17.65	10.69	4.71	6.13	15.25	10
Mar	2.68	59.49	0.00	12.19	5.43	2.21	2.96	15.05	22
Apr	1.32	49.56	5.76	6.42	6.71	3.02	5.37	21.83	40
May	2.19	38.44	0.00	40.31	1.75	1.06	2.50	13.75	20
Jun	0.27	3.24	0.00	22.70	2.05	1.73	9.46	60.54	20
Aug	1.14	28.41	0.00	14.77	4.89	1.36	5.45	43.98	16
Sep	1.86	47.14	2.53	13.52	3.44	1.48	2.97	27.07	35
Oct	1.07	60.67	0.00	7.47	9.80	2.72	5.61	12.67	30
Nov	2.80	42.05	7.99	15.56	7.39	4.27	5.54	14.41	75
Dec	2.31	32.09	9.72	5.40	11.68	4.72	8.42	25.67	51
ANNUAL	1.92	43.49	5.14	11.25	8.16	3.55	5.84	20.66	348

Table 4.6. Month-wise 'index of preponderance' of food items in females of *S. choprai.*

Month	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminiferan shells	Sand	Detritus	No. of shrimps
Jan	1.70	35.12	12.55	7.13	11.52	3.33	5.01	23.63	36
Feb	2.96	37.59	5.44	17.57	11.47	4.78	4.44	15.75	28
Mar	1.45	58.81	6.67	7.14	4.52	1.91	2.97	16.52	18
Apr	0.76	41.96	16.78	9.12	6.70	2.72	4.13	17.84	40
May	2.24	57.11	0.00	15.26	1.97	1.11	3.11	19.21	20
Jun	0.27	12.16	9.46	42.57	2.03	1.51	9.19	22.81	20
Aug	1.25	35.00	0.00	36.52	2.77	1.34	3.84	19.29	20
Sep	1.15	41.39	9.63	8.29	6.51	2.09	3.46	27.49	35
Oct	1.32	37.54	0.00	29.12	6.35	2.16	5.30	18.21	30
Nov	2.31	53.36	7.37	6.89	6.70	3.16	5.58	14.63	54
Dec	3.19	59.68	0.00	9.35	7.01	3.28	5.48	12.01	50
ANNUAL	1.91	44.04	8.54	11.12	8.14	3.08	4.83	18.32	351

Table 4.7. Results of statistical analysis of variance of food in males and females of *S. choprai.*

Food item with sex		**SS**	**Df**	**mS**	**F**	**Sig.**
Decapod crustaceans	Between Groups	1498	1	1497.76	3.58	**NS**
	Within Groups	291210	697	417.81		
	Total	292708	698			
Digested matter	Between Groups	0	1	0.10	0.00	**NS**
	Within Groups	42169	697	60.50		
	Total	42169	698			
Foraminiferans	Between Groups	0	1	0.32	0.16	**NS**
	Within Groups	1402	697	2.01		
	Total	1403	698			
Fish remains	Between Groups	194	1	193.80	2.76	**NS**
	Within Groups	48869	697	70.11		
	Total	49063	698			
Polychaetes	Between Groups	152	1	151.60	2.02	**NS**
	Within Groups	52249	697	74.96		
	Total	52401	698			
Small crustaceans	Between Groups	6	1	5.70	2.24	**NS**
	Within Groups	1775	697	2.55		
	Total	1780	698			
Sand	Between Groups	0	1	0.27	0.06	**NS**
	Within Groups	3080	697	4.42		
	Total	3081	698			
Molluscan shells	Between Groups	9	1	9.39	0.69	**NS**
	Within Groups	9502	697	13.63		
	Total	9511	698			
Stomach fullness	Between Groups	5074	1	5074.48	4.79	**<0.05**
	Within Groups	738905	697	1060.12		
	Total	743980	698			

Table 4.8. 'Index of preponderance' of food items in different size groups of males of *S. choprai.*

Length-range (mm)	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminiferan shells	Sand	Detritus	No. of shrimps
< 65	1.95	37.35	6.04	3.26	7.88	4.06	7.83	31.64	34
66-70	1.19	46.33	5.79	5.90	8.79	3.72	6.82	21.46	64
71-75	1.99	42.46	4.71	13.53	7.85	3.03	4.80	21.63	89
76-80	1.71	41.13	4.58	12.29	9.19	4.14	6.17	20.80	94
81-85	2.38	50.72	4.94	12.91	6.72	3.44	5.50	13.41	55
>85	0.76	36.41	20.65	7.99	6.52	2.39	4.78	20.49	12

Table 4.9. Results of statistical analysis of variance of food in different size groups of males of *S. choprai*

Food item with male size		SS	Df	mS	F	Sig.
Decapod crustaceans	Between Groups	16875	32	527.36	1.38	NS
	Within Groups	120376	315	382.15		
	Total	137252	347			
Digested matter	Between Groups	3096	32	96.76	1.41	NS
	Within Groups	21620	315	68.63		
	Total	24716	347			
Foraminiferans	Between Groups	53	32	1.67	0.91	NS
	Within Groups	581	315	1.84		
	Total	634	347			
Fish remains	Between Groups	2083	32	65.09	1.04	NS
	Within Groups	19669	315	62.44		
	Total	21752	347			
Polychaetes	Between Groups	460	32	14.39	1.17	NS
	Within Groups	3872	315	12.29		
	Total	4333	347			
Small crustaceans	Between Groups	2512	32	78.51	1.13	NS
	Within Groups	21864	315	69.41		
	Total	24377	347			
Sand	Between Groups	39	32	1.23	0.60	NS
	Within Groups	651	315	2.07		
	Total	691	347			
Molluscan shells	Between Groups	173	32	5.39	1.20	NS
	Within Groups	1421	315	4.51		
	Total	1593	347			
Stomach fullness	Between Groups	42494	32	1327.94	1.43	NS
	Within Groups	293373	315	931.34		
	Total	335867	347			

Table 4.10. 'Index of preponderance' of food items in different size groups of females of *S. choprai.*

Length-range (mm)	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminifer-an shells	Sand	Detritus	No. of shrimps
<70	0.00	61.11	0.00	3.33	7.41	5.00	7.59	15.56	4
71-75	0.05	50.29	13.03	6.57	7.05	2.79	4.87	15.35	26
76-80	1.14	32.39	20.33	6.55	6.42	3.23	4.15	25.80	31
81-85	1.73	40.49	6.34	17.53	6.43	3.06	4.98	19.44	70
86-90	2.43	43.09	9.85	10.81	8.28	2.98	4.69	17.87	88
91-95	2.80	52.97	4.02	10.54	7.25	2.77	4.45	15.19	85
96-100	1.71	40.55	5.95	15.49	9.77	4.57	5.76	16.21	33
>100	3.53	53.25	0.00	21.63	6.56	2.09	3.34	9.60	14

Table 4.11. Results of statistical analysis of variance of food in different size groups of females of *S. choprai.*

Food item with female size		**SS**	**Df**	**mS**	**F**	**Sig.**
Decapod crustaceans	Between Groups	33312	39	854.16	2.20	**<0.01**
	Within Groups	120646	311	387.93		
	Total	153958	350			
Digested matter	Between Groups	4814	39	123.44	3.04	**<0.01**
	Within Groups	12639	311	40.64		
	Total	17453	350			
Foraminiferans	Between Groups	238	39	6.10	3.58	**<0.01**
	Within Groups	530	311	1.70		
	Total	768	350			
Fish remains	Between Groups	4095	39	105.01	1.42	**NS**
	Within Groups	23022	311	74.03		
	Total	27117	350			
Polychaetes	Between Groups	1587	39	40.70	3.53	**<0.01**
	Within Groups	3582	311	11.52		
	Total	5169	350			
Small crustaceans	Between Groups	6461	39	165.66	2.41	**<0.01**
	Within Groups	21412	311	68.85		
	Total	27872	350			
Sand	Between Groups	160	39	4.09	1.38	**NS**
	Within Groups	924	311	2.97		
	Total	1084	350			
Molluscan shells	Between Groups	329	39	8.45	2.27	**<0.01**
	Within Groups	1157	311	3.72		
	Total	1487	350			
Stomach fullness	Between Groups	119333	39	3059.83	3.35	**<0.01**
	Within Groups	283705	311	912.23		
	Total	403038	350			

Table 4.12. Maturity stage-wise 'index of preponderance' of food items of female of *S. choprai.*

Maturity stage	Small crustaceans	Decapod crustaceans	Polychaetes	Fish remains	Molluscan shells	Foraminifer-an shells	Sand	Detritus	No. of shrimps
Immature	0.00	43.99	21.49	4.74	7.41	3.20	5.26	13.90	14
Early Maturing	2.00	40.60	10.12	12.89	7.81	3.14	4.13	19.30	130
Late maturing	3.73	47.83	0.16	13.27	8.70	3.81	6.44	16.07	77
Mature	1.99	65.36	0.09	11.97	5.42	2.25	5.00	7.93	34
Spent	1.61	43.31	9.67	12.19	6.90	2.75	4.18	19.39	96

Table 4.13. Results of statistical analysis of variance of food in different maturity stages of females of *S. choprai*

Food item with female maturity stages		**SS**	**Df**	**mS**	**F**	**Sig.**
Decapod crustaceans	Between Groups	4764	4	1191.12	2.76	**<0.05**
	Within Groups	149194	346	431.20		
	Total	153958	350			
Digested matter	Between Groups	776	4	193.97	4.02	**<0.01**
	Within Groups	16677	346	48.20		
	Total	17453	350			
Foraminiferans	Between Groups	4	4	0.99	0.45	**NS**
	Within Groups	764	346	2.21		
	Total	768	350			
Fish remains	Between Groups	92	4	23.12	0.30	**NS**
	Within Groups	27025	346	78.11		
	Total	27117	350			
Polychaetes	Between Groups	23	4	5.77	0.39	**NS**
	Within Groups	5146	346	14.87		
	Total	5169	350			
Small crustaceans	Between Groups	1372	4	343.02	4.48	**<0.01**
	Within Groups	26500	346	76.59		
	Total	27872	350			
Sand	Between Groups	12	4	2.96	0.96	**NS**
	Within Groups	1072	346	3.10		
	Total	1084	350			
Molluscan shells	Between Groups	18	4	4.45	1.05	**NS**
	Within Groups	1469	346	4.25		
	Total	1487	350			
Stomach fullness	Between Groups	11450	4	2862.62	2.53	**<0.05**
	Within Groups	391588	346	1131.76		
	Total	403038	350			

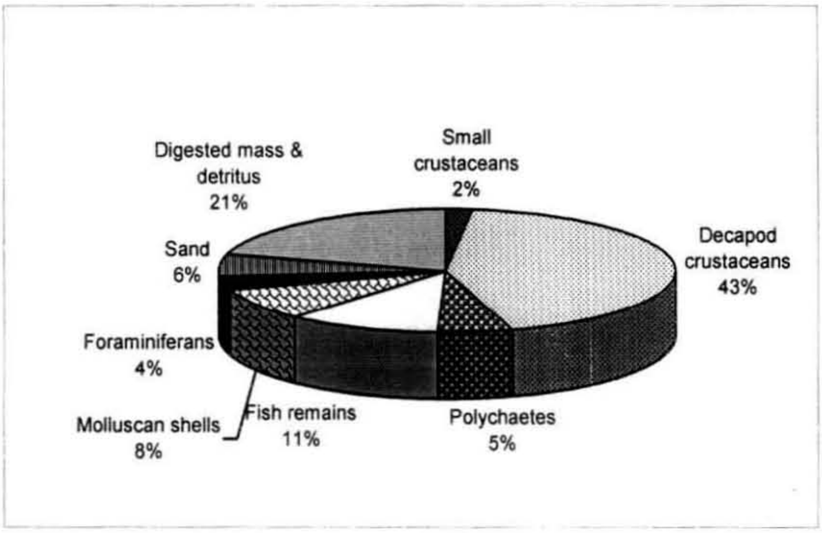


Fig. 4.1. Annual diet composition of males of *S. choprai.*

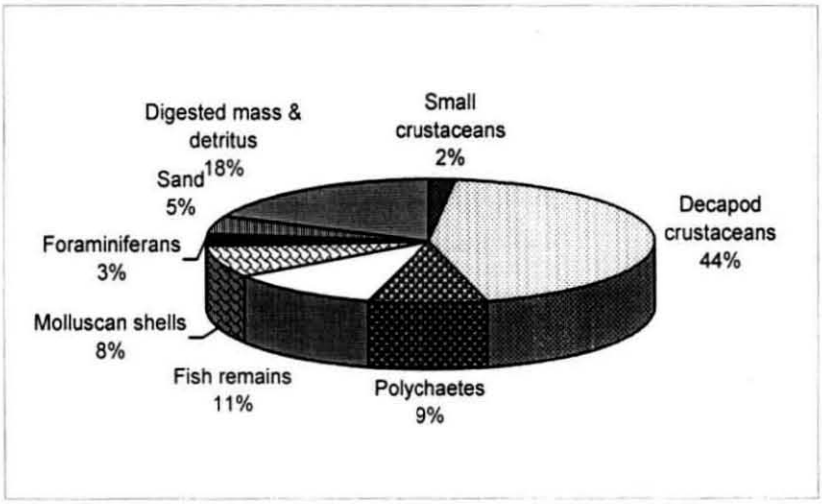


Fig. 4.2. Annual diet composition of females of *S. choprai.*

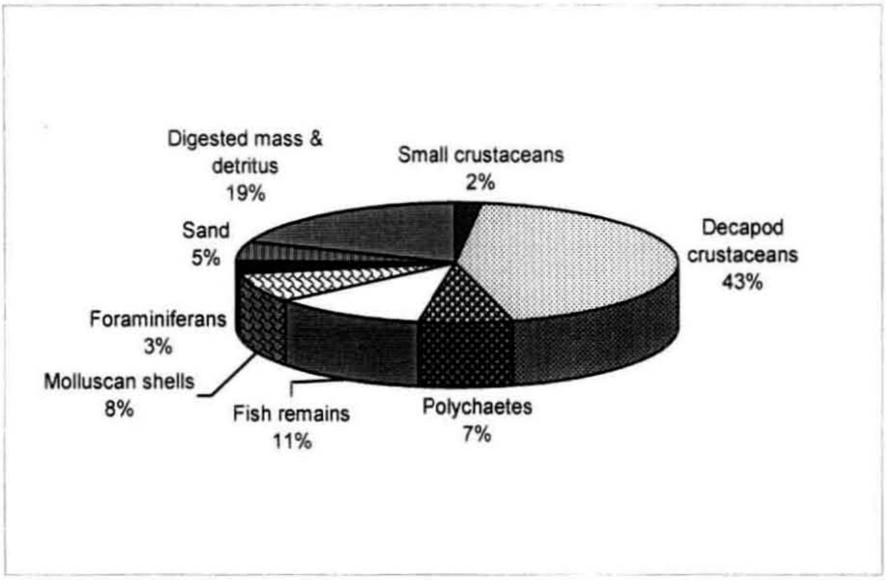


Fig. 4.3. Annual diet composition of *S. choprai* (adults-both sexes pooled).

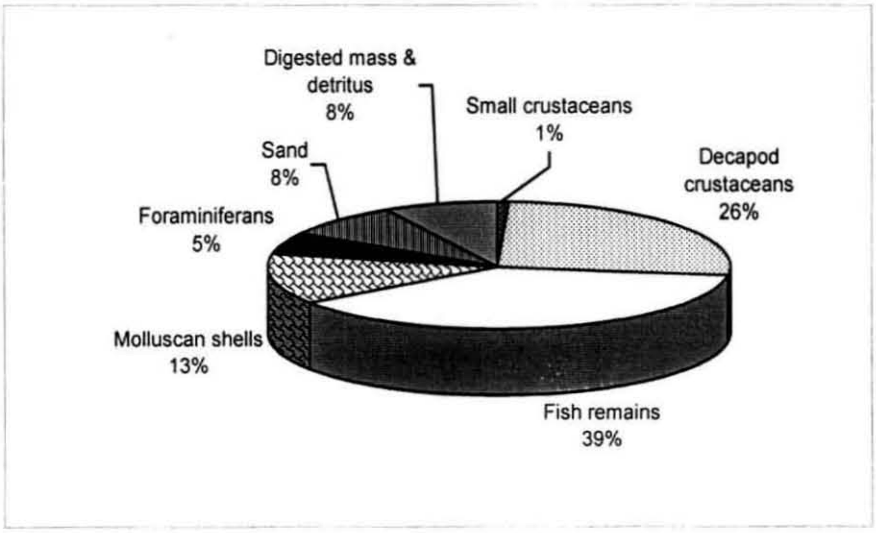


Fig. 4.4. Diet composition of juveniles of *S. choprai.*

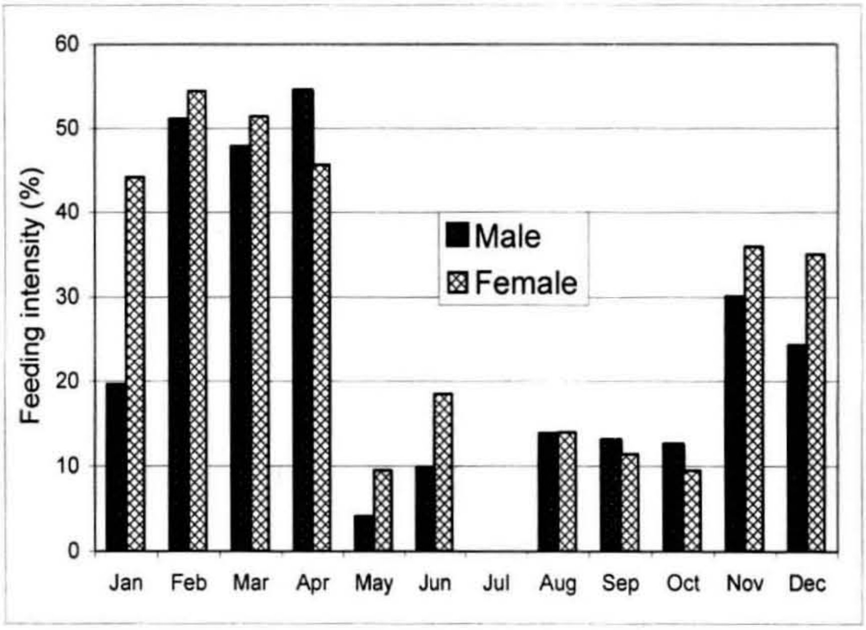


Fig. 4.5. Month-wise feeding intensity in males and females of *S. choprai*.

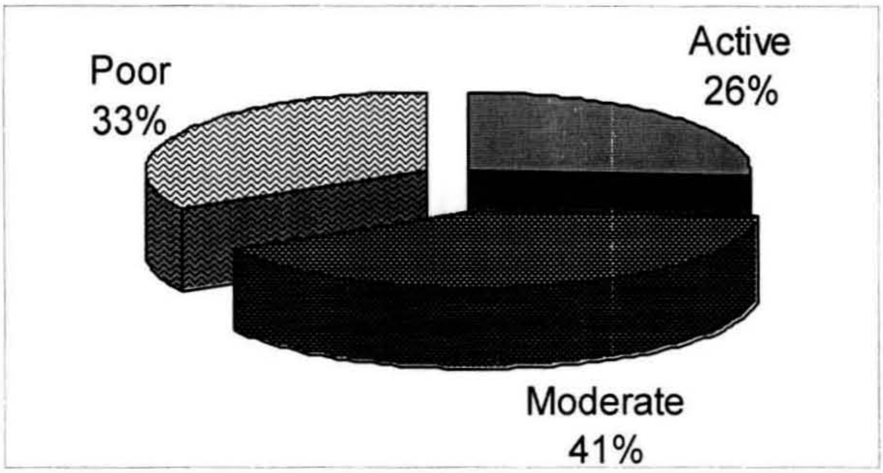


Fig. 4.6. Feeding condition in juveniles of *S. choprai* in November.

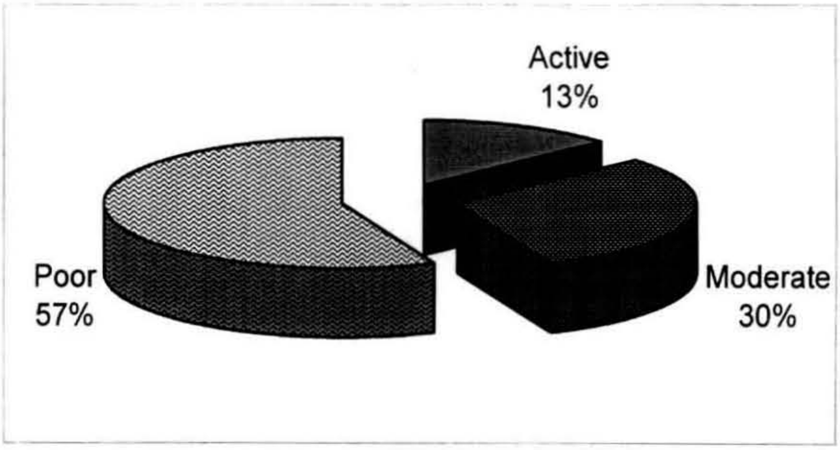


Fig. 4.7. Annual feeding condition of males of *S. choprai*.

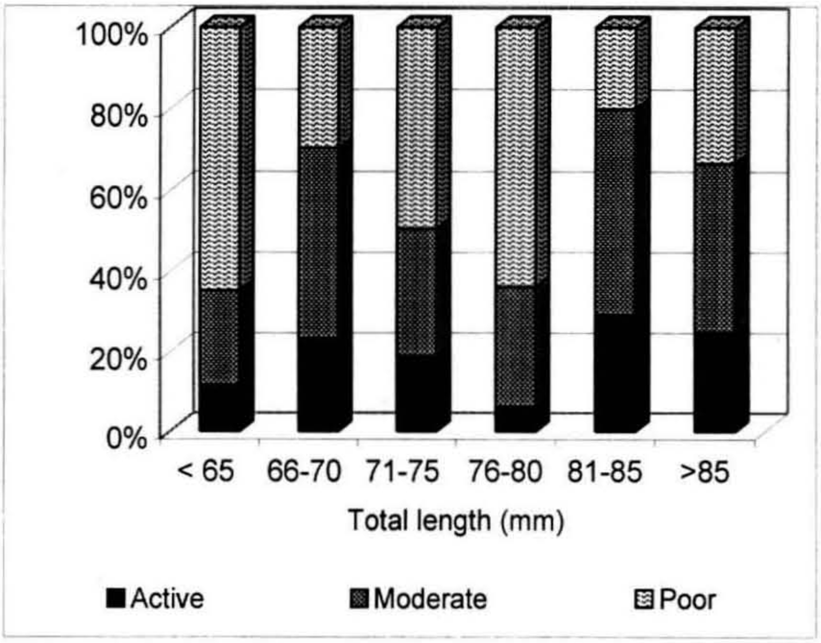


Fig. 4.8. Size-wise annual feeding intensity in males of *S. choprai*.

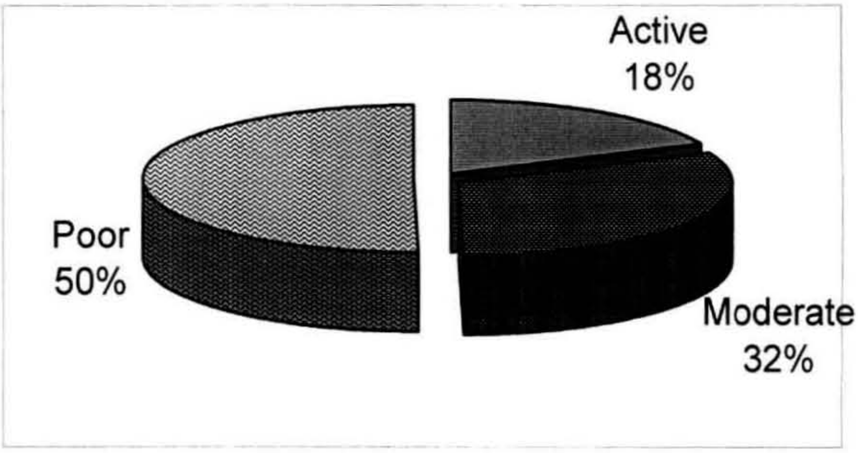


Fig. 4.9. Annual feeding condition in females of *S. choprai*.

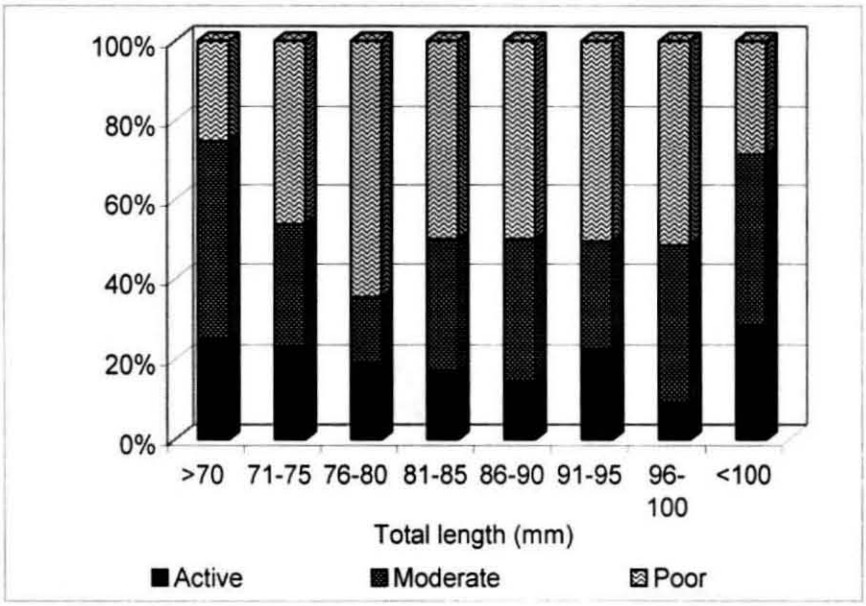


Fig. 4.10. Size-wise annual feeding intensity in females of *S. choprai*.

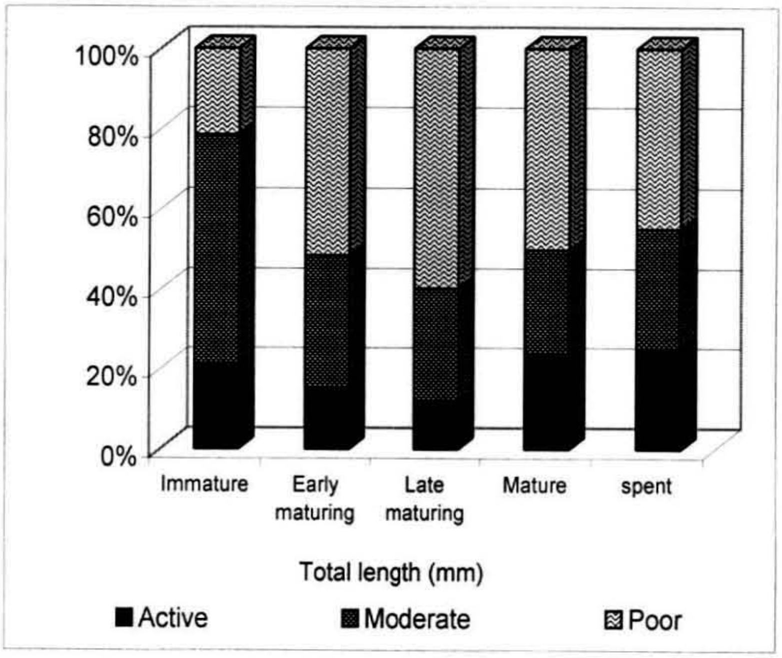


Fig. 4.11. Maturity stage-wise annual feeding intensity in females of *S. choprai.*

4.5. Reproduction

4.5. REPRODUCTION

4.5.1. RESULTS

4.5.1.1. Reproductive organs

4.5.1.1.1. Structure of male reproductive system

The male reproductive system in *S.choprai* consists of a pair of testes, vas deferens, terminal ampoules and a petasma (Fig. 5.1). The testes consist of four lobes located in the cardiac region dorsal to hepatopancreas. The narrow tube which follows this portion is the vas deference that traverses through muscle of cephalothorax and opens at the base of 5^{th} pereopod through the terminal ampoule (Fig. 5.2). The petasma is formed by the fusion of endopods of first pair of pleopods.

4.5.1.1.2. Structure of female reproductive system

The female reproductive system in *S. choprai* consists of ovaries, oviducts and a single thelycum (Fig. 5.1). The mature ovaries are paired organs, situated dorsally extending from the base of rostrum to the last abdominal segment. They are bilaterally symmetrical and partly fused. Each half of the ovary consists of three lobes of which the slender anterior lobe occupies the cephalic region and lies in close proximity with the oesophagus and cardiac region of the stomach. The middle lobe has six finger-like lateral lobules. The lateral lobules are located dorsally to the large mass of hepatopancreas and ventrally to the pericardial chamber. The posterior lobes of the ovary extend the entire length of the abdomen. The two halves of the ovary are united, one at the base of the anterior lobe and other at the tip of the posterior lobe in the 6th abdominal segment. The thin oviducts start from the tip of the penultimate lobules of the middle lobe on both side and run downwards to the external gonophore on the 3rd pereopod (Fig. 5.2).

4.5.1.2. Maturation

4.5.1.2.1. Maturity stages in females

4.5.1.2.1.1. By gross examination of ovary

Based on the coloration and size of the ovary and ova-diameter variations, five stages of maturity in females of *S. choprai* were identified following Rao (1989) as: immature, early maturing, late maturing, mature and spent-recovering.

The ova-diameter frequency distribution of maturing ova in different lobes and in different stages of maturity in females of *S. choprai* is shown in Figs. 5.3 and 5.4.

<u>Immature stage</u>: The ovary is thin, translucent and unpigmented confined to posterior part of cephalothorax and abdomen.

<u>Early maturing stage</u>: Size of the ovary increases, anterior lobes further develop and extend forward in the cephalothorax; the middle lobes and rudiments of their lobule develop. The posterior lobe increases in girth. The general colour of the ovary is yellowish.

Late maturing stage: The ovary develops further, the anterior, middle and posterior lobes fill the cephalothorax completely. The ovary is generally orange in colour, some times with branched brownish chromatophores distributed over the surface. Ovary is clearly visible through the exoskeleton.

Mature stage: The ovary is very clearly visible through exoskeleton. The anterior and middle lobes are well developed. The colour of the ovary is brownish orange. Due to the fullness of the ovary, the lateral lobules of the middle lobe get folded and occupy the entire space available in the cephalothorax.

Spent recovering stage: After extrusion of ova, the gonad reverts almost immediately to immature condition. The ovarian lobes are flaccid and appear whitish. The ovary contains ova which are similar to those in immature stage.

The external view of ovary during progressive maturity stages is given in Fig. 5.5.

4.5.1.2.1.2. Microscopic studies of ova

Immature stage: A microscopic examination of immature ovary revealed that ovary contains tiny ova with clear cytoplasm and conspicuous nuclei. The diameter of the ova varied from 1 to 6 micrometer divisions (md), but the majority falls between 2 and 3 md (0.03 to 0.05 mm).

Early maturing stage: The ovary in this stage contains two groups of ova *viz.*, immature and developing. The developing ova are translucent due to accumulation of yolk in the cytoplasm and ova-diameter measure between 4 and 13 micrometer divisions with majority between 7 to 9 md (0.11 to 0.14 mm).

Late maturing stage: The developing ovum is opaque and the nucleus become completely invisible (Fig. 5.6). Size range of the developing ova-diameter was 10 to 18 micrometer divisions with majority of them distributed between 15 and 16 md (0.23 to 0.24 mm).

Matured stage: The mature ova are opaque and fully yolked. Cortical crypts were found in the periphery of the ova (Fig. 5.6). The diameters of the ova were between 16 and 23 micrometer divisions with majority of them having a diameter of 19 to 21 md (0.29 to 0.32 mm)

Spent-recovering stage: The ovary contains ova which are similar to those in immature stage. This stage is distinguished from immature virgin females based on the relative size of the shrimp. In the spent-recovering stages, the eggs were found to have a size of 1 to 6 md (0.02 to 0.09 mm), quite similar to immature stages. The frequency of ova-diameter distribution is given in Tables 5.1 and 5.2.

4.5.1.2.1.3. Gonado-somatic index (GSI)

Minimum, maximum and mean values of GSI, found out for females of different maturity stages are given in Table 5.3. To ensure that GSI was independent of the body size, GSI was regressed against the total length (after log transformation) (West, 1990). In the present study it was seen that there is no significant correlation between GSI and total length of the shrimp, which indicated that GSI is independent of female size (Correlation coefficient, r^2 value was 0.055437) (Table 5.4). The gonado-somatic index of *S. choprai* in various stages of ovary development is presented in Fig. 5.7.

4.5.1.2.2. Size at first maturity

Male: As in other penaeid shrimps, the petasma in *S. choprai* is formed by the modification of endopods of the first pleopod. Joining of the petasma along with the presence of spermatophores in the terminal ampoule indicate the onset of male maturity (Bealde, 1992). In the present study the smallest male in mature condition with well developed petasma and having visible spermatophores in the terminal ampoule measured 52 mm. To determine the size at first maturity, 133 males of the size range of 51-58 mm (total length) were examined and details are given in Table 5.5. It was noticed that 50% of the observed males attain maturity at 55 mm (Fig. 5.8). Hence, the size at first maturity (50%) in males of *S. choprai* was estimated as 55 mm. All the males above 58 mm were mature.

Female: During the course of this study, smallest female having mature ovary was found to have a total length of 62 mm. To decide the size at first maturity, a total number of 829 females measuring between 61 and 77 mm were considered. The frequency of distribution of mature females indicated that the minimum size at first maturity (50%) of *S. choprai* was 66 mm and all those measuring 78 mm and above were matured (Table 5.6 and Fig. 5.9).

4.5.1.3. Spawning

4.5.1.3.1. Spawning season

The monthly percentage occurrence of different stages of maturity in females of *S. choprai* is given in Tables 5.7 and 5.8. During 2003, the percentage of matured females was the highest during November (23.96%) with the peak extending till December. During January and March also the percentage of matured females were comparatively high (Figs. 5.10 and 5.11). In 2004 again, the highest percentage of matured females were seen in November (26.67%) with another peak in January and February. Good percentage of matured females was also observed in August 2004 (Figs. 5.12 and 5.13). From these observations, it can be inferred that *S. choprai* is a continuous breeder with two peek breeding seasons. To understand the relationship with mean monthly GSI values and spawning season, the monthly mean GSI values and the percentage of matured females were compared (Figs. 5.16 and 5.17). Mean GSI values also showed similar trend as observed in the case of matured females.

4.5.1.3.2. Spawning population

The details on the lengthwise distribution of *S. choprai* in different stages of ovarian maturity for the years 2003 and 2004 and data pooled for both years are given in Tables 5.9, 5.10 and 5.11 and Figs. 5.14 and 5.15. During 2003, females of *S. choprai* in the size range of 91-110 mm formed the major spawning population of the fishery whereas in 2004 the smaller size range of 81-90 mm formed the major spawning population.

4.5.1.3.3. Spawning frequency

Based on the information on lengthwise distribution of mature females of *S. choprai* (Tables 5.9, 5.10 and 5.11) the following inferences could be made. Matured females showed dominant modes at 91-95, 106-110 mm in 2003 and at 86-90 mm in 2004. To get more accurate picture of spawning frequency, the females of both the years were pooled and were arranged in 2 mm size classes (Table 5.12). It is seen that the females at a size ranges of 73-74 mm, 93-94 mm and 103-104 mm have higher percentages of matured ones and it can be assumed that the shrimp breeds at least three times before attaining 104 mm.

4.5.1.4. Fecundity

The number of ova present in the ovary of mature females of *S. choprai* in the size range of 79 mm and 110 mm has been estimated in the present work. The details on the total length, total body weight, ovary weight and the estimated number of ova are given in Table 5.13. It was observed that, when compared to other coastal penaeid shrimps, *S. choprai* has low fecundity. The estimated number of ova in the matured ovary ranged from 38,532 to 1,33,689 in *S. choprai* measuring 80 mm and 110 mm (TL) respectively.

4.5.1.4.1. Relationship between fecundity and total length, body weight and ovary weight

Fecundity increased generally with increase in size. In order to identify the factor which could be used as a best predictor of fecundity, regression analysis was carried out between of fecundity and total length, total weight and ovary weight. The correlation coefficients between log fecundity and log total length, log total body weight and log ovary weight are given in Table 5.14. It can be observed that there were no significant difference in the coefficient of prediction (r^2) using these three variables and can be inferred that ovary weight could be used as a single best predictor for fecundity of *S. choprai* and is more reliable than total length and body weight. The relation is given as:

Log fecundity = 10.99881 + 0.867432 log ovary weight

Fecundity = 59802.64 x Ovary weight $^{0.867342}$

4.5.1.5. Sex ratio

4.5.1.5. 1. Month-wise and annual sex ratio

The monthly percentage composition of females and males of *S. choprai* in the catches of shrimp trawlers at Mangalore and Malpe during 2003-2004 is given in Table 5.15. Overall, females and males were found in more or less equal proportions (51:49). The annual sex ratio during the years 2003 and 2004 also showed similar percentage composition. The χ^2 test showed that the annual distribution of females and males is not significantly different from 1:1 ratio at 1% level. In the monthly sex ratio of females to males, significant variation from 1:1 ratio at 1% level was observed during January and February in 2003 and February, April, November and December in 2004. During January, April, November and December 2004, the percentage of males were significantly higher than females, whereas female percentage was significantly higher during February, 2003 and February, 2004 (Table 5.15).

4.5.1.5. 2. Size-wise sex ratio

During 2003-04, 3,275 shrimps were analysed to derive the size-wise sex composition and found that 1,618 were males and 1,657 were females (Table 5.16). The size-wise analysis (5 mm interval) showed that as the length range increases the percentage of females is also increasing, leading to subsequent reduction in male percentage (Fig. 5.18). Beyond length of 94 mm, all the shrimps observed were females.

4.5.2. DISCUSSION

There is little consistency among various workers who have studied the maturation of ovaries in shrimps as to the number of stages of maturity recognised. King (1948) recorded five stages in *P. setiferus* and Cummings (1961) described only four in *P.duorarum*. Shaikmahmud and Tembe (1961) differentiated between spent and regenerating females in *P. stylifera* to give five stages. Renfro and Brusher (1964) classified the developmental stages of *P. setiferus* as seven stages whereas Oka and Shirhata (1965) recognised eight maturity stages in *P. orientalis*. Based on the coloration and size of the ovary and ova-diameter variations, five stages of maturity in females of *S. choprai* were recognised in the present work which agrees with the observations of Ohtomi *et al.* (1998) in *S. melantho* and Baelde (1992) in *Haliporoides sibogae*.

The mature ova are fully yolked with the diameter measuring between 0.24 mm and 0.35 mm and majority of them have an ova-diameter of 0.29 to 0.32 mm. The present findings is in agreement with that of Aravindakshan and Karbari (1994) who observed that the ova-diameter of *S. choprai* from Bombay water varied from 0.20 to 0.30 mm. Microscopic examination of mature ova during the present study showed the formation of cortical crypts at the periphery of the ova. Similar cortical crypts formation was reported by Anderson *et al.* (1984) in *Sicyonia ingentis* and Ohtomi *et al.* (1998) in *S. melentho.* Ohtomi *et al.* (1998) described appearance of cortical crypts as a sign of commencement of spawning in *S. melentho.*

Maturity of male shrimps was determined by various workers. Burukovskij (1980) working on deepwater shrimp *Plesiopenaeus edwadsianus* used junction of petasma as an indicator of sexual maturity. But Baelde (1992) working on another deep sea species *H. sibogae* stated that the junction of petasma occurred well before the spermatophores were fully developed and suggested that swelling of terminal ampoules was a better criterion of male sexual development of this species. During the present study presence of joined petasma along with swelling of terminal ampoule was considered as criteria for determining male maturity. It was found that the size at first maturity (50%) was 66 mm (16 mm CL) and 55 mm (12 mm CL) in females and males respectively. The attaining of maturity in smaller sizes in males compared to females was reported from Indian waters by various workers. (Rao, 1968; Sukumaran, 1978 and Nandakumar, 1997). Previous record on size at first maturity of *S. choprai* is not available from India or abroad for the comparison of the present results. In Japanese waters *S. melantho* was found to mature at a size of 25.3 mm (CL) which is much higher than that found in *S. choprai*. Based on the result of growth studies in the present work, it is estimated that male and female *S. choprai* attains a length of 68 and 85 mm respectively at the end of first year. Since the size at first maturity has been estimated at 55 and 66 mm in males and females respectively, the shrimp is able to mature and spawn before they complete one year of its life (in 8 to 9 months) (from 'age and growth' studies). Similar finding was reported in *S. acuminata* from French Guiana (Gueguen, 1998).

The simultaneous occurrence of females at all stages of maturity and presence of ripe oocytes throughout the season indicate that *S. choprai* is a continuous breeder. Ohtomi *et al.* (1998) recorded similar activity in *S. melantho* and Baelde (1992) in *H. sibogae.* Such multiple spawning was also recorded in several coastal species by various authors. Aravindakshan and Karbari (1994) found maximum number of matured females in the fishery in September. During the present study gravid females were found throughout the season, but during October-December, the percentages of spawners were the highest.

It is reported that in penaeid shrimps fecundity ranges from 2, 50,000 to 9, 50,000 oocytes (Penn, 1980) and mean oocyte diameter ranges from 0.25 to 0.35 mm (Levi and Vaachi, 1988 and Tan Fermin and Pudadera, 1989). Fecundity in *S. choprai* ranged between 38,532 and 1, 33,689 during the present study. Maximum number of ova (1,33,689) were found in the female having a total length of 110 mm (TL) which is in agreement with the findings of Aravinkshan and Karbari (1994), who estimated the fecundity of *S. choprai* as 1,30,850 for a female of 107 mm (TL), from Bombay waters. When compared with big sized penaeid shrimps the fecundity of *S. choprai* is low. But, when size-wise comparison is made this result is comparable with the studies of Rao (1968) who reported that a female *M. dobsoni* of 70 mm (TL) produced 34,500 ova and another female of 120 mm (TL) produced 1,64,000 ova; *M. affinis* of 95 mm (TL) produced 88,000 ova and *P. stylifera* of 70 mm (TL) produced 39,500 ova.

During the present study the sex ratio of *S. choprai* was not significantly different from 1:1. But in landings dominated by smaller shrimps, the sex ratio was found to show a domination of males and in the landings dominated by bigger sized shrimps, the sex ratio is dominated by females. Size-wise sex ratio showed a sigmoid increase in female sex ratio.

The sigmoid increase in sex ratio which followed as size increase has been observed in many species of marine crustaceans (Werner, 1972 and Penn, 1980). Baelde (1992) reported that, sex ratio for total population of royal shrimps was close to 50%, but it varied markedly with the size of shrimps. The significance in change in sex ratio of young shrimps is questionable because of the general low abundance of these shrimps in commercial catches. Difference in growth, migration behaviour between males and females and changes in mortality and catchability particularly after breeding were attributed as the possible factors effecting the changes in sex ratio in different size groups (Werner, 1972, King and Moffit, 1984 and King, 1986).

Table 5.1. Ova-diameter frequency distribution (in percentage) of maturing ova in different lobes of a mature ovary.

Ova-diameter (md)	Anterior lobe %	Middle lobe %	Posterior lobe %	Pooled %
15	0	0	0.00	0
16	0.33	0.67	1.67	0.89
17	2.00	2.00	6.00	3.33
18	10.00	9.33	10.67	10.00
19	19.67	21.00	28.67	23.11
20	36.67	47.33	40.00	41.33
21	22.00	15.33	10.33	15.89
22	7.00	4.00	2.67	4.56
23	2.33	0.33	0.00	0.89
No. of ova	300	300	300	900

md = micrometer division

Table 5.2. Ova-diameter frequency distribution (in percentage) of maturing ova in different stages of maturity in *S. choprai.*

Ova- diameter (md)	Stages of maturity (percentage)				
	IMM	EM	LM	MA	SP
1	19.20				20.60
2	31.20				50.20
3	33.07				22.92
4	14.40	0.08			4.97
5	1.93	1.40			1.05
6	0.20	8.43			0.27
7		26.97			
8		31.47			
9		14.12			
10		9.20	0.20		
11		7.20	2.57		
12		1.00	8.13		
13		0.13	13.93		
14			21.87		
15			26.83		
16			20.70	0.17	
17			5.63	1.60	
18			0.13	9.90	
19				20.50	
20				40.40	
21				19.60	
22				6.93	
23				0.90	

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.3. Gonado-somatic index (GSI) in females of *S. choprai* in various stages of ovary development during 2003-2004.

Maturity stages	GSI range		Mean	No. of shrimps
	Min	Max		
IMM	0.162	1.487	0.582	58
EM	0.824	6.16	2.28	159
LM	3.151	12.544	7.189	144
MA	10.757	16.286	13.647	13
SP	0.181	1.583	0.751	150
Total				3108

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.4. Regression statistics of total length and GSI in females of *S. choprai.*

Regression Statistics	
Multiple R	0.235451
R Square	**0.055437**
Adjusted R Square	0.053631
Standard Error	3.276985
Observations	3108

Table 5.5. Determination of size at first maturity in males of *S. choprai.*

Total length (mm)	No. of shrimps	No. of shrimps in maturing stage	Maturing %
51	2	0	0
52	10	1	0
53	10	3	10
54	14	6	30
55	19	11	43
56	20	14	58
58	25	25	70

Table 5.6. Determination of size at first maturity in females of *S. choprai.*

Total length (mm)	No. of shrimps	No. of shrimps in maturing stage	Maturing %
61	0	0	0.00
62	14	2	14.29
63	15	4	26.67
64	24	8	33.33
65	22	8	36.36
66	8	4	50.00
67	55	31	56.36
68	84	54	64.29
69	6	4	66.67
70	34	24	70.59
71	18	13	72.22
72	117	90	76.92
73	110	90	81.82
74	94	81	86.17
75	70	62	88.57
76	68	62	91.18
77	86	82	95.35

Table 5.7. Monthly occurrence of maturity stages in females of *S. choprai* in 2003.

Month	Stages of maturity					No. of shrimps observed
	IMM	EM	LM	MA	SP	
Jan	9.09	32.32	41.41	5.05	12.12	92
Feb	0.00	38.36	15.07	2.74	43.84	73
Mar	4.76	35.71	35.71	9.52	14.29	42
Apr	2.92	54.39	22.22	1.75	18.71	171
May	9.29	50.00	19.29	2.14	19.29	140
Jun	14.29	50.79	14.29	0.00	20.63	63
Aug	1.68	38.66	21.85	0.00	37.82	117
Sep	4.55	45.15	18.79	0.61	30.91	330
Oct	2.05	44.62	34.36	0.51	18.46	195
Nov	1.56	17.71	40.10	23.96	16.67	192
Dec	10.25	34.43	29.92	8.61	16.80	244
Total						1659

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.8. Monthly occurrence of maturity stages in females of *S. choprai* in 2004.

Month	Stages of maturity					No. of shrimps observed
	IMM	EM	LM	MA	SP	
Jan	8.43	31.33	33.73	9.64	16.87	83
Feb	35.19	25.93	19.44	13.89	5.56	108
Mar	12.99	37.29	19.21	4.52	25.99	177
Apr	23.72	30.77	21.79	3.85	19.87	156
May	10.77	22.31	37.69	0.77	28.46	130
Jun	26.51	27.71	15.66	1.20	28.92	83
Aug	1.43	30.00	34.29	17.14	17.14	70
Sep	3.80	32.49	30.38	4.64	28.69	237
Oct	5.34	30.58	34.47	6.80	22.82	206
Nov	0.00	29.33	40.00	26.67	4.00	75
Dec	0.00	48.39	27.42	10.48	13.71	124
Total						1449

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.9. Size-wise distribution of maturity stages in females of *S. choprai* in 2003.

Size group	Stages of maturity					No. of shrimps observed
	IMM	EM	LM	MA	SP	
< 70mm	100.00	0.00	0.00	0.00	0.00	38
71-75	27.27	36.36	13.64	0.00	22.73	100
76-80	10.00	48.06	16.13	3.23	22.58	141
81-85	0.00	34.29	12.86	7.14	45.71	319
86-90	0.00	47.73	21.59	5.68	25.00	401
91-95	0.00	23.53	25.88	23.53	27.06	387
96-100	0.00	36.36	39.39	6.06	18.18	150
101-105	0.00	46.15	38.46	7.69	7.69	59
106-110	0.00	7.14	21.43	28.57	42.86	64
Total						1659

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.10. Size-wise distribution of maturity stages in females of *S. choprai* in 2004.

Size group (mm)	Stages of maturity					No. of shrimps observed
	IMM	EM	IM	EM	IM	
< 70	91.36	4.10	2.20	0.00	0.00	181
71-75	8.64	11.88	4.63	4.24	14.43	135
76-80	0.00	21.38	12.68	17.80	16.84	221
81-85	0.00	21.38	28.29	20.34	23.37	307
86-90	0.00	18.14	20.49	26.27	17.18	249
91-95	0.00	15.55	16.83	14.41	15.12	202
96-100	0.00	5.83	10.00	13.56	8.93	110
101-105	0.00	1.30	3.41	1.69	3.09	31
106-110	0.00	0.00	0.24	0.85	0.34	3
111-115	0.00	0.00	0.24	0.85	0.34	3
Total						1449

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.11. Size-wise distribution of maturity stages in females of *S. choprai* during 2003-2004 (pooled).

Size group (mm)	Stages of maturity					No. of shrimps observed
	IMM	EM	IM	EM	IM	
< 70	87	9	4	0	0	219
71-75	18	39	14	2	28	235
76-80	4	46	21	7	22	362
81-85	0	33	25	7	34	626
86-90	0	42	26	8	23	650
91-95	0	28	29	18	25	589
96-100	0	31	38	10	20	260
101-105	0	37	41	7	15	90
106-110	0	9	25	26	40	74
111-115	0	0	33	33	33	3
Total						3108

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.12. Lengthwise (2 mm class interval) maturity stages of females of *S. choprai* to determine spawning frequency.

Length range (mm)	Stages of maturity					No. of shrimps observed
	IMM	EM	IM	EM	IM	
61-62	89	11	0	0	0	9
63-64	68	21	11	0	0	19
65-66	60	33	7	0	0	15
67-68	39	54	6	1	0	69
69-70	35	55	10	0	0	20
71-72	15	49	15	3	19	68
73-74	10	48	23	**20**	0	102
75-76	10	45	19	4	22	69
77-78	2	38	30	3	28	105
79-80	5	42	17	3	33	66
81-82	0	44	19	3	34	94
83-84	0	35	36	4	24	124
85-86	0	35	30	3	32	139
87-88	0	40	36	6	18	150
89-90	0	38	29	4	29	112
91-92	0	43	28	11	18	127
93-94	0	31	35	**14**	20	124
95-96	0	32	22	11	35	91
97-98	0	39	39	10	11	71
99-100	0	33	30	0	37	30
101-102	0	37	47	5	11	19
103-104	0	36	36	**14**	14	14
105-106	0	17	67	0	17	6

IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Table 5.13. Fecundity of *S. choprai.*

Total length (mm)	Total wt (g)	Ovary wt. (g)	GSI	Fecundity (Number of ova)
79	6.73	0.78	11.59	48, 444
80	6.99	0.74	10.60	38, 532
81	7.22	0.98	13.50	56, 550
82	7.51	0.81	10.76	54, 045
83	7.72	0.79	10.25	43, 434
87	8.81	1.26	14.26	61, 544
88	9.12	0.98	10.72	64, 122
89	9.41	0.96	10.20	60, 465
90	9.38	1.17	12.43	76, 231
92	10.3	1.68	16.31	80, 864
95	11.04	1.50	13.61	88, 097
96	11.62	1.48	12.74	76, 150
97	11.16	1.55	13.87	1, 00, 620
98	12.16	1.66	13.65	1, 04, 513
99	12.58	1.35	10.73	80, 000
100	12.67	1.63	12.86	1, 02, 969
101	12.82	1.37	10.65	81, 900
102	13.77	1.41	10.24	88, 773
104	13.86	1.88	13.56	1, 12, 800
105	14.86	1.82	12.24	99, 312
106	15.18	2.37	15.60	1, 08, 739
108	16.06	2.49	15.50	1, 18, 410
110	16.45	2.50	15.22	1, 33, 689

Table 5.14. Results of the statistical analysis to find the best predictor of fecundity.

Relations analysed	r	r^2
1. log fecundity with log total length	0.9391	0.8818
2. log fecundity with log total weight.	0.9287	0.8626
3. log fecundity with ovary weight	0.9567	0.9037
log fecundity =	10.99881 + 0.867432 log ovary weight	
Fecundity =	**59802.64 x ovary weight $^{0.867342}$**	

Table 5.15. Monthly sex ratio (in percentage) of *S. choprai* (based on the estimated numbers in thousands)

Month	Observed numbers			Percentage		χ^2 Value	Significance
	Male	Female	Total	Male	Fema le		
Jan	24013	10955	34968	68.67	31.33	6.972	**S**
Feb	4733	11915	16649	28.43	71.57	9.304	**S**
Mar	1260	2406	3666	34.38	65.63	4.883	**NS**
Apr	14605	19512	34117	42.81	57.19	1.034	**NS**
May	19988	28428	48416	41.28	58.72	1.519	**NS**
Jun	306	536	843	36.36	63.64	3.719	**NS**
Aug	718	615	1333	53.88	46.12	0.300	**NS**
Sep	69913	67068	136981	51.04	48.96	0.022	**NS**
Oct	21034	24561	45595	46.13	53.87	0.299	**NS**
Nov	7412	6875	14286	51.88	48.12	0.071	**NS**
Dec	2810	3117	5927	47.41	52.59	0.134	**NS**
Jan	3268	2432	5700	57.34	42.66	1.077	**NS**
Feb	1705	4601	6306	27.04	72.96	10.544	**S**
Mar	3100	3579	6679	46.41	53.59	0.257	**NS**
Apr	9624	4087	13711	70.19	29.81	8.154	**S**
May	2180	1750	3930	55.47	44.53	0.598	**NS**
Jun	554	506	1061	52.26	47.74	0.102	**NS**
Aug	181	235	416	43.55	56.45	0.833	**NS**
Sep	2834	3152	5986	47.34	52.66	0.141	**NS**
Oct	4740	7828	12569	37.72	62.28	3.018	**NS**
Nov	1274	589	1862	68.38	31.62	6.755	**S**
Dec	863	314	1177	73.33	26.67	10.889	**S**
Annual 2003	166794	175987	342782	48.65	51.35	0.036	**NS**
Annual 2004	30323	29073	59396	51.06	48.94	0.022	**NS**
2003 & 2004 Pooled	197117	205061	402178	49.02	50.98	0.020	**NS**

S = significant at 1% level; **NS** = Not significant at 5% level.

Table 5.16. Size-wise sex composition of *S. choprai.*

Size group (mm)	No. of shrimps observed		Percentage	
	Male	Female	Male	Female
61-65	158	36	81.44	18.56
66-70	298	100	74.87	25.13
71-75	414	141	74.59	25.41
76-80	431	325	57.01	42.99
81-85	208	402	34.10	65.90
86-90	86	371	18.82	81.18
91-95	23	150	13.29	86.71
96-100	0	67	0.00	100.00
101-105	0	55	0.00	100.00
106-110	0	8	0.00	100.00
111-115	0	2	0.00	100.00
Total	1618	1657		

EXTERNAL REPRODUCTIVE ORGANS

FEMALE **MALE**

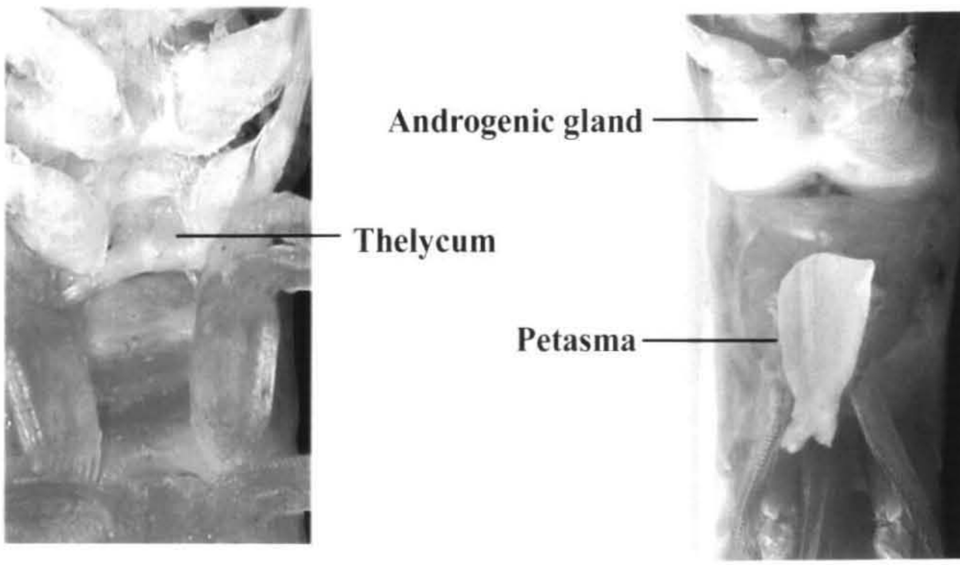


Fig. 5.1. External reproductive organs of *S. choprai.*

REPRODUCTIVE SYSTEM

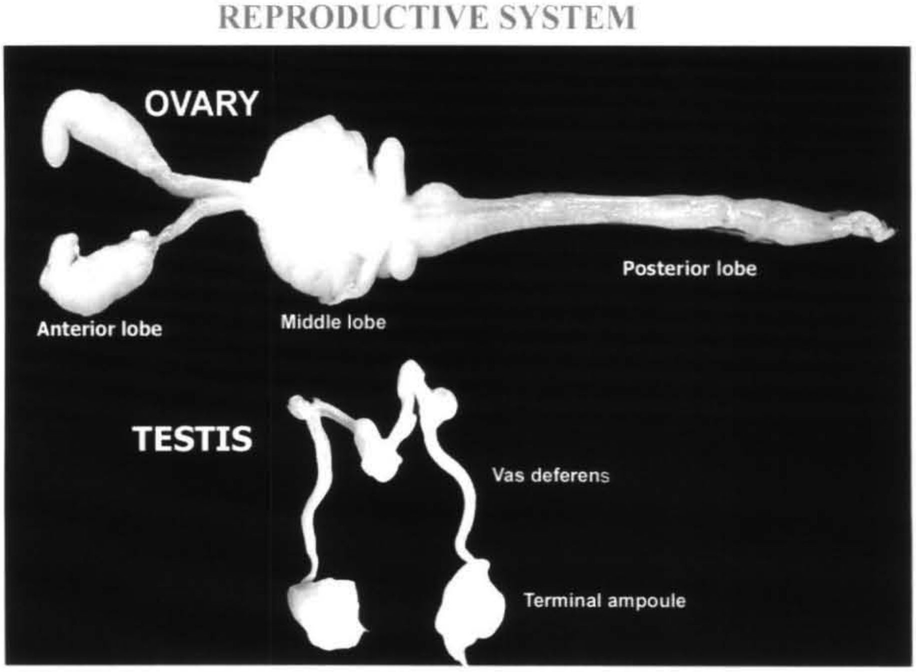


Fig. 5.2. Ovary and testis of *S.choprai.*

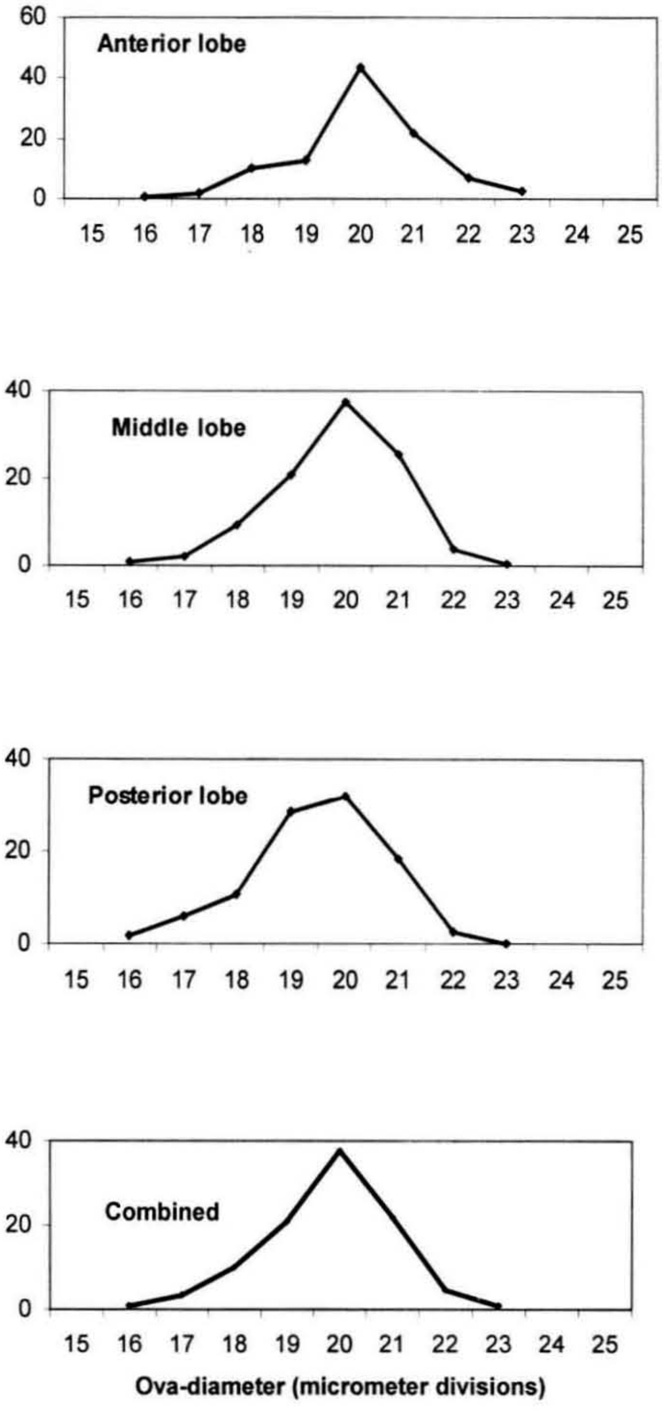


Fig. 5.3. Ova-diameter frequency distribution (in percentage) of maturing ova in different lobes of a matured ovary.

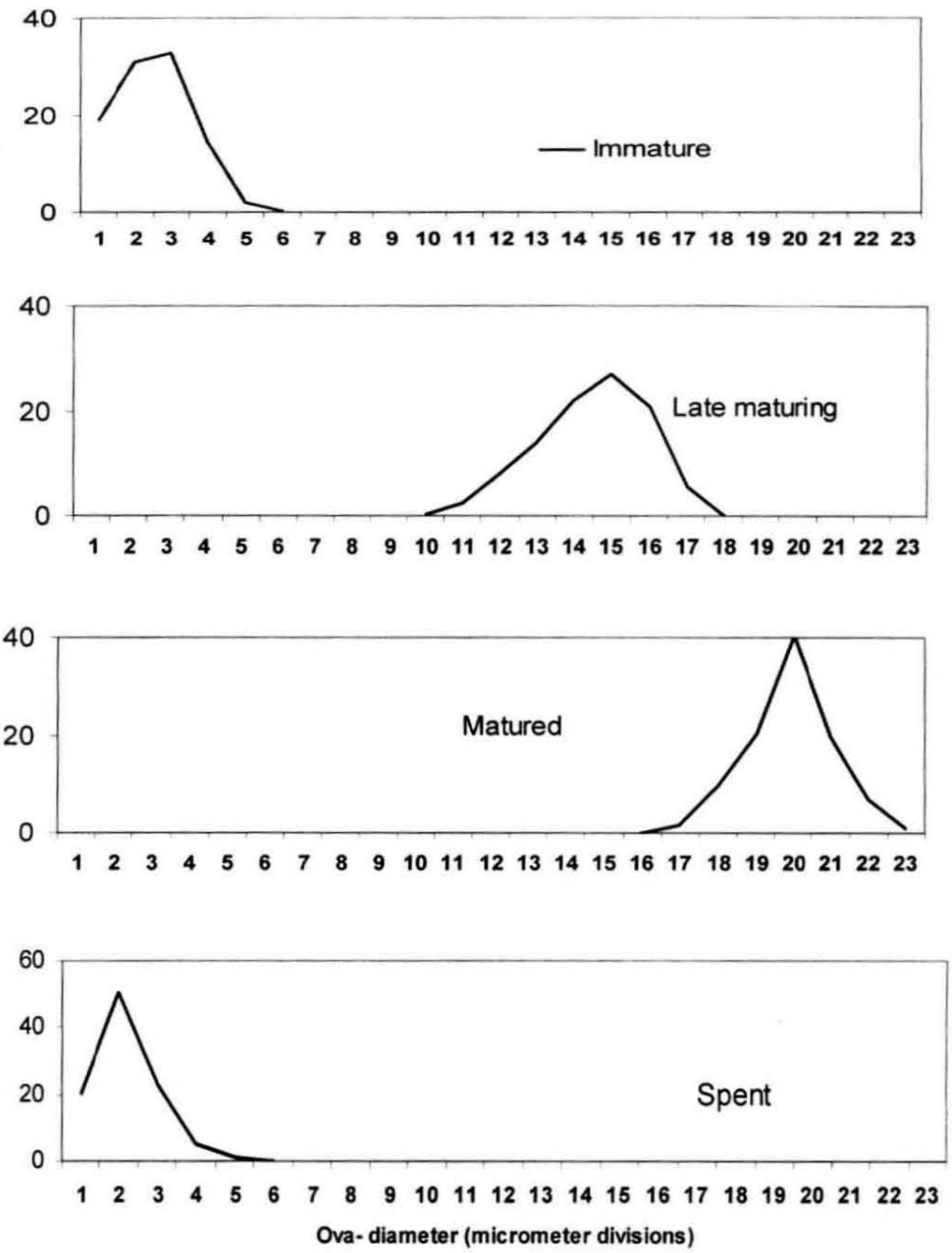


Fig. 5.4. Ova-diameter frequency distribution (in percentage) of maturing ova in different stages of maturity in *S. choprai*.

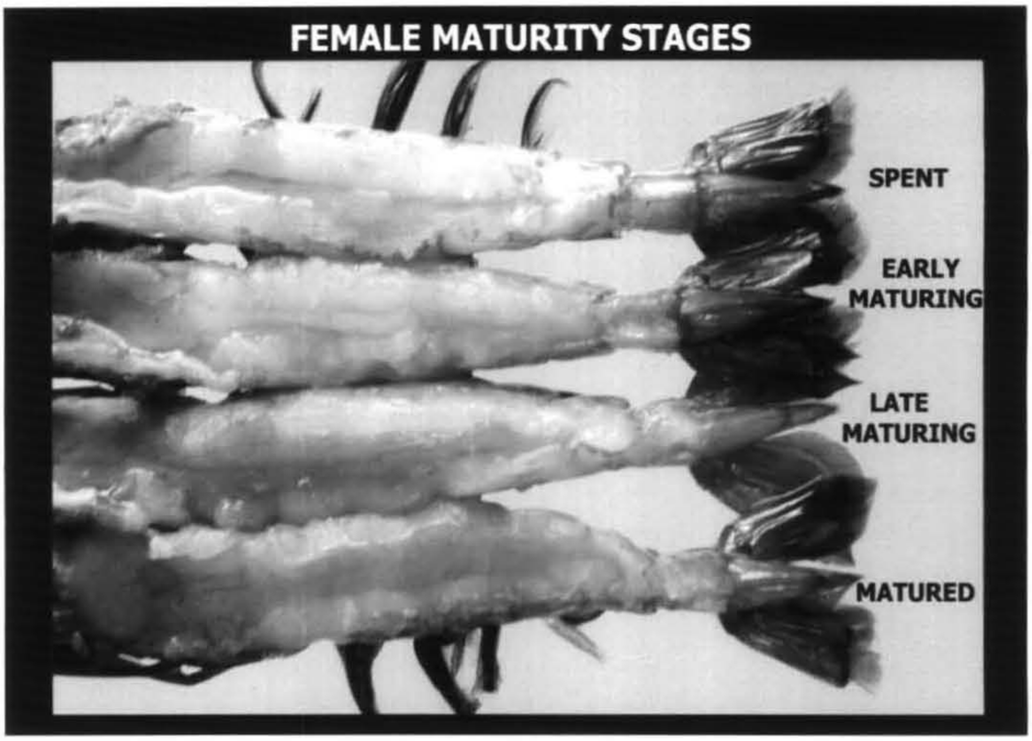


Fig. 5. 5. External identification of maturity stages of *S.choprai* females.

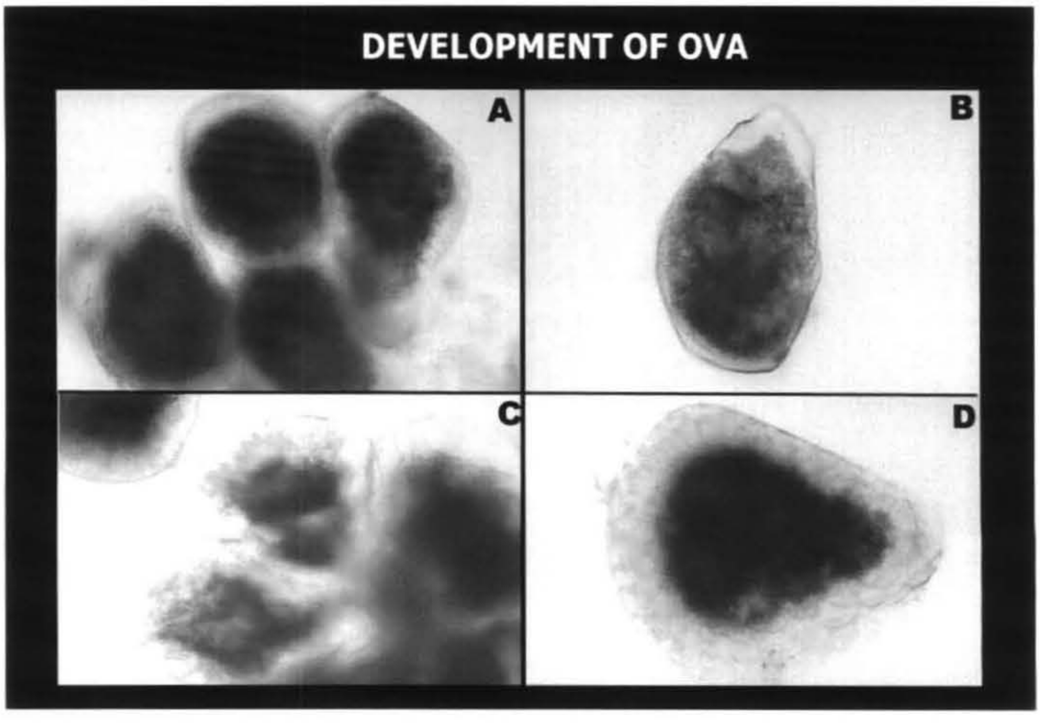


Fig. 5. 6. Maturing and matured ova.
A. maturing ova ; B. maturing ovum; C. matured ova; D. matured ovum.

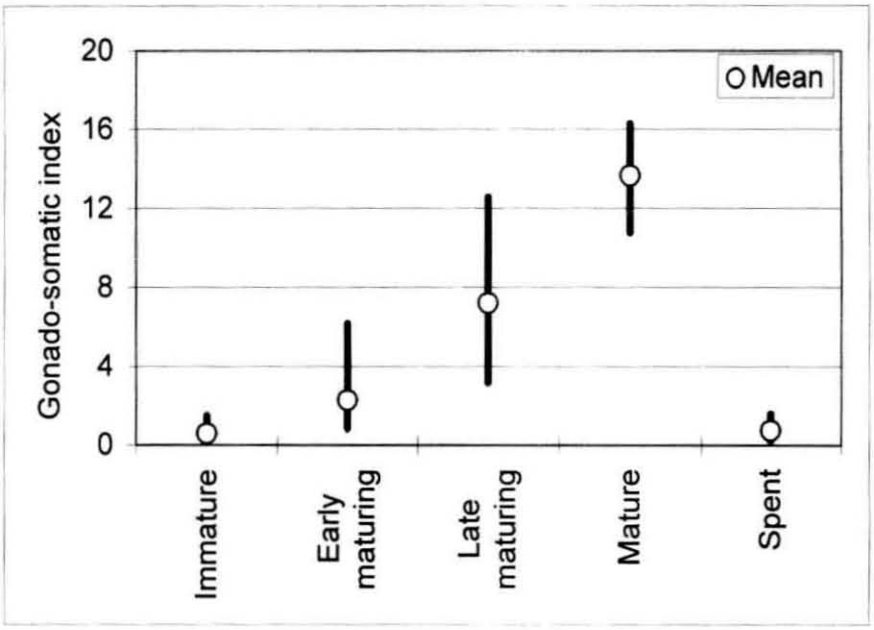


Fig. 5.7. Gonado-somatic index (GSI) of *S. choprai* (females) during various stages of ovary development.

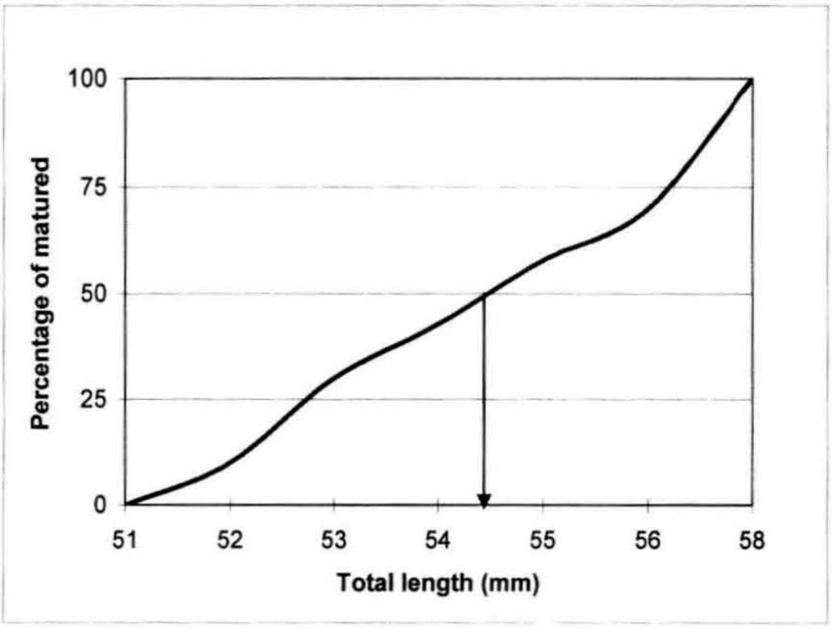


Fig. 5.8. Determination of size at maturity curve for males of *S. choprai.*

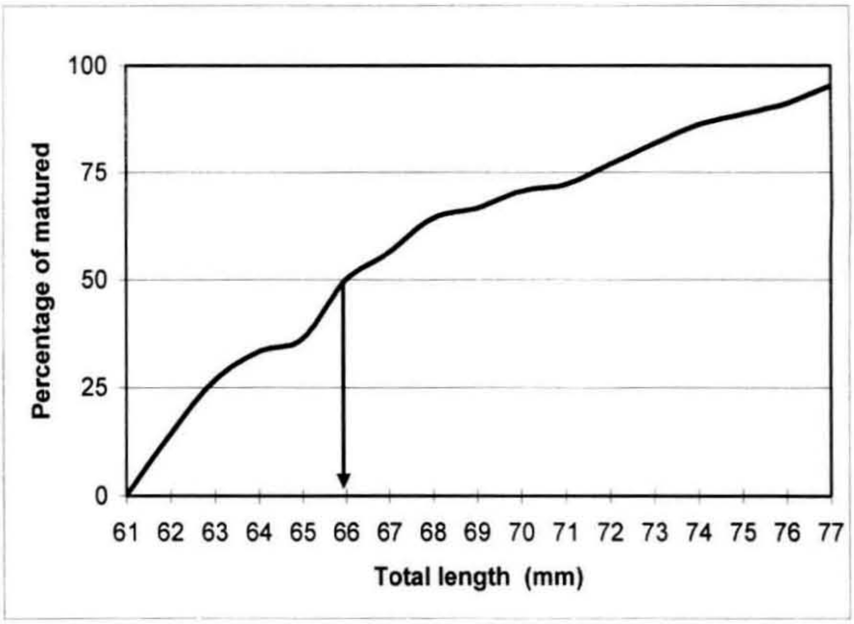
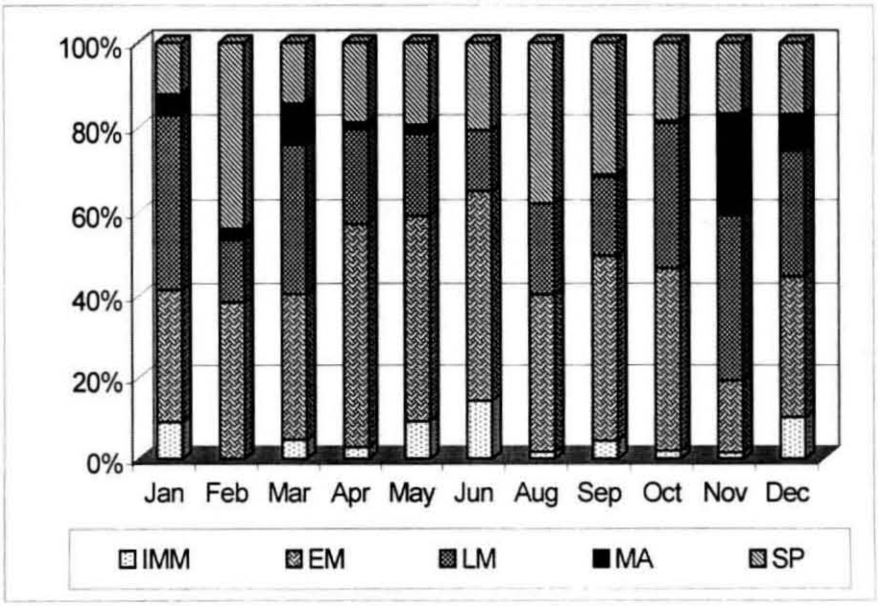


Fig. 5.9. Determination of size at maturity curve of females of *S. choprai* .



Imm = immature; **Em** = early maturing; **Lm** = late maturing; **Ma** = mature; **Sp**= spent

Fig. 5.10. Monthly occurrence of maturity stages in females of *S. choprai* in 2003.

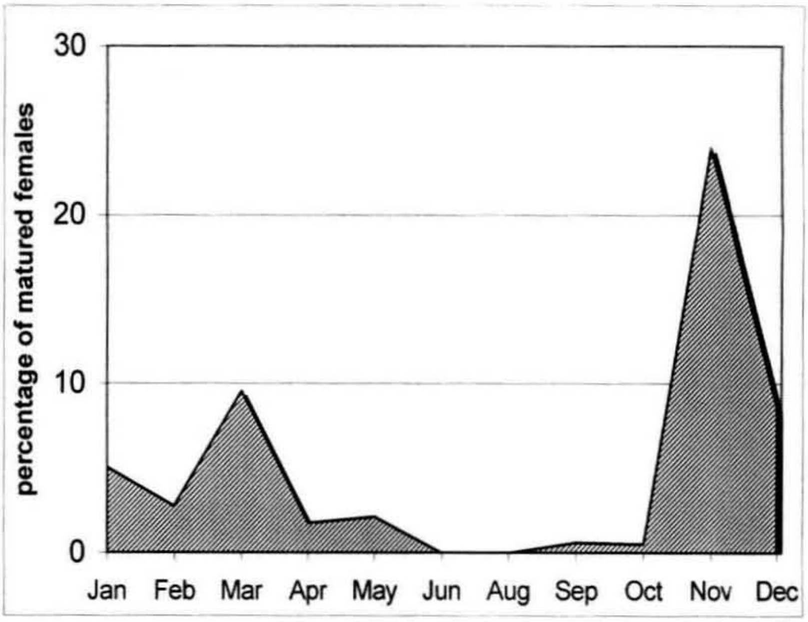
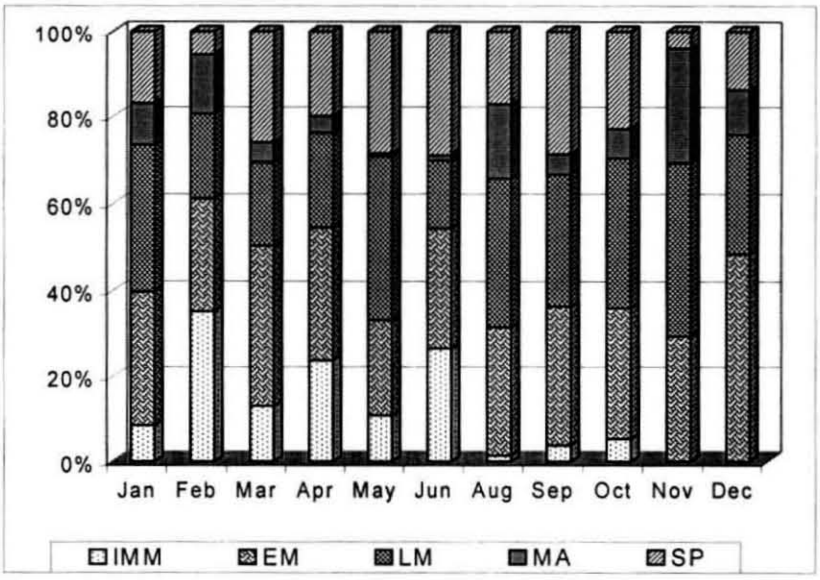


Fig. 5.11. Monthly percentage of matured females in 2003.



IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Fig. 5.12. Monthly occurrence of maturity stages in females of *S. choprai* in 2004.

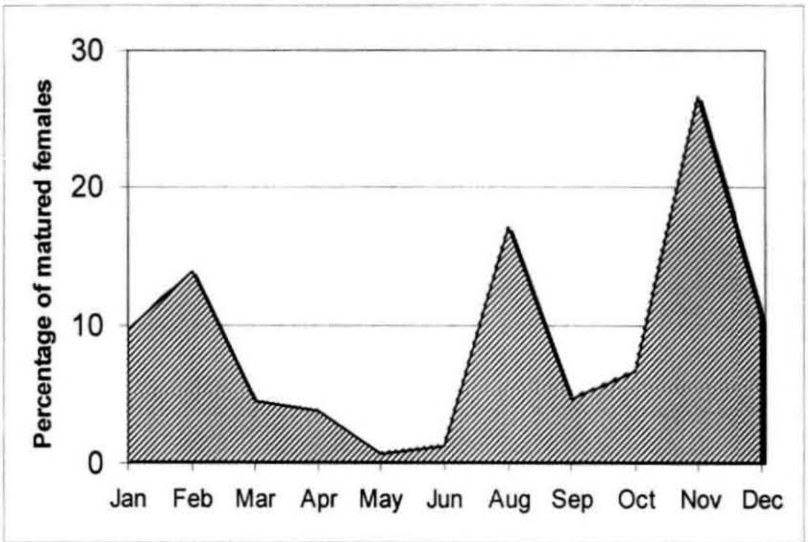
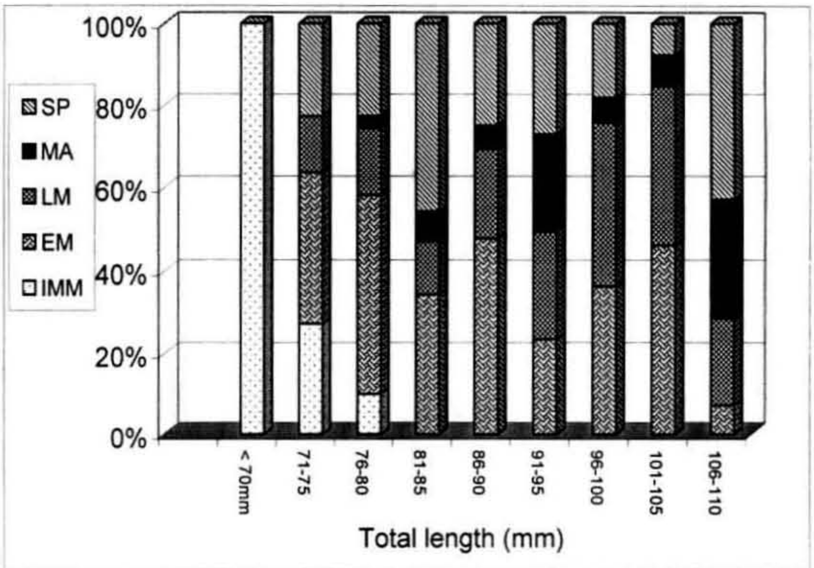


Fig. 5.13. Monthly percentage of matured females of *S. choprai* in 2004.



IMM = immature; **EM** = early maturing; **LM** = late maturing; **MA** = mature; **SP** = spent

Fig. 5.14. Size-wise distribution of maturity stages of females of *S. choprai* in 2003.

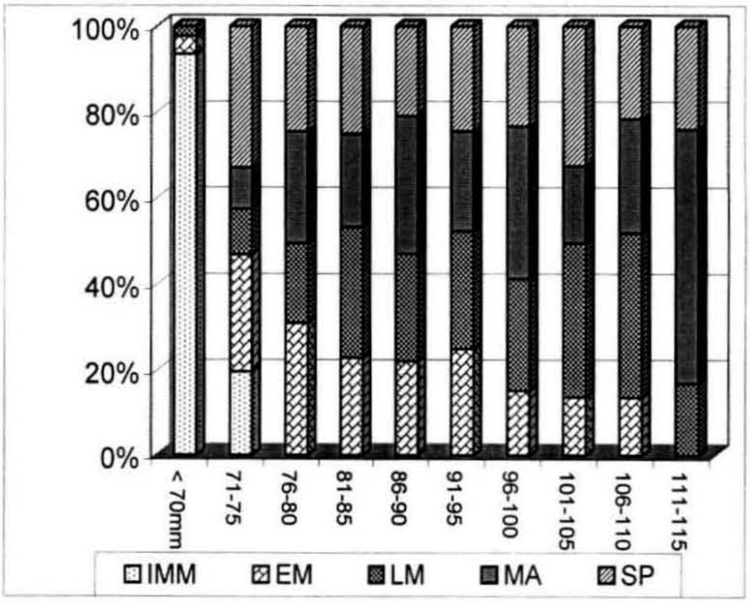


Fig. 5.15. Size-wise distribution of maturity stages in females of *S. choprai* in 2004.

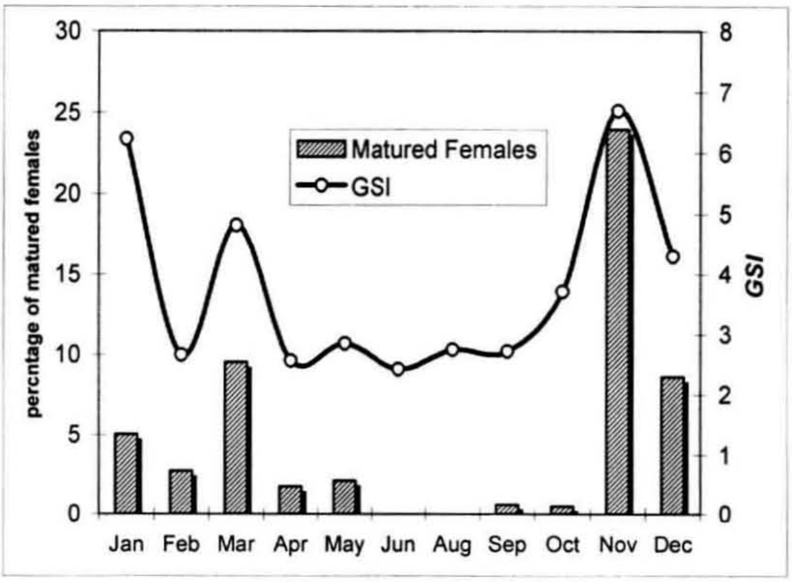


Fig. 5.16. Percentage of matured females and monthly average gonado-somatic index (GSI) of *S. choprai* in 2003.

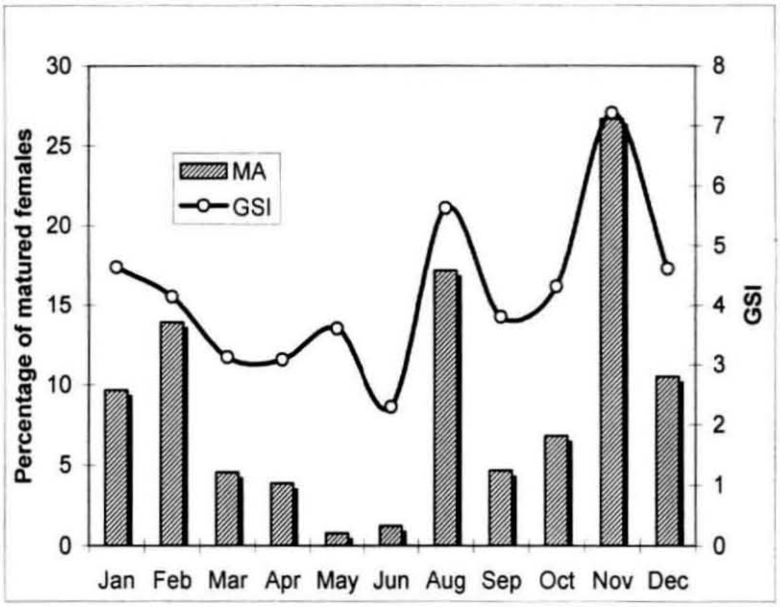


Fig. 5.17. Percentage of matured females and monthly average gonado-somatic index (GSI) of *S. choprai* in 2004.

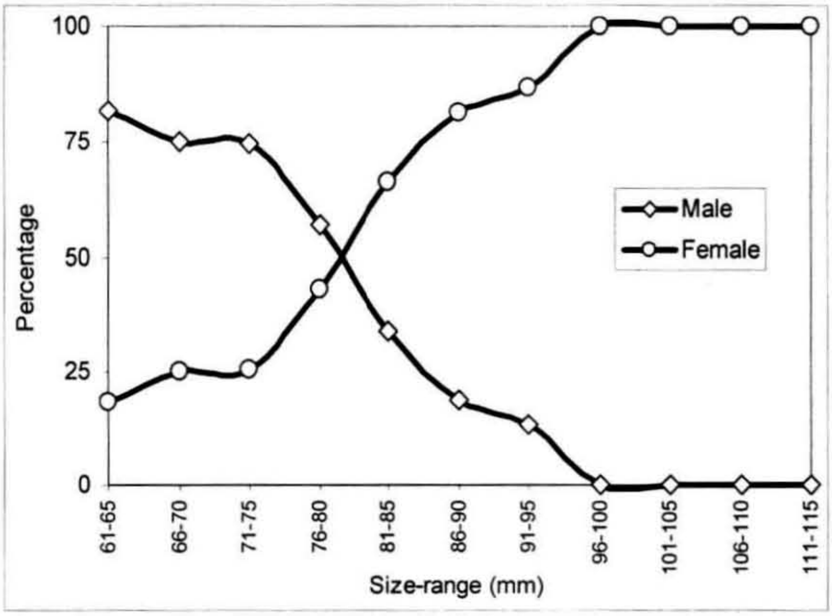


Fig. 5.18. Size-wise sex composition of *S. choprai.*

4.6. Age and Growth

4. 6. AGE AND GROWTH

4.6.1. RESULTS

4.6.1.1. Length-frequency and mean length

The month-wise size-frequency distribution of *S. choprai* (males, females and sex pooled) landed at Mangalore and Malpe fisheries harbours during 2003-2004 is given in Tables 6.1, 6.2 and 6.3. The total length of males ranged from 46 to 95 mm, with size range of 76-80 mm dominating the fishery in 2003 and 71-80 mm in 2004. Mean length of males was 74 mm in 2003, which was reduced to 72 mm in 2004. In the case of females, the length ranged from 50 to 110 mm during 2003-2004. Maximum number was caught in the length class 91-95 mm in 2003 and 81-85 mm in 2004. Here also reduction in mean size was noticed and the mean size in 2003 was 86.3 mm which dropped to 82.7 mm in 2004. Drop in mean size along with reduction in landings indicate a reduction in the stock. When data of both sexes pooled, it is seen that maximum number was caught in the length range of 71-85 mm in 2003 and 65-85 mm in 2004, which confirms that smaller sized shrimps dominated the fishery in the second year.

4.6.1.2. Estimation of growth parameters

4.6.1.2.1. Male

The data used for fitting regression for the estimation of growth parameters using Powell-Wetherall method are shown in Table 6.4. The L_∞

obtained by Powell-Wetherall method was 97.3 mm and $Z/K = 3.87$ (Fig. 6.1). The L_∞ obtained from ELEFAN I with an R_n value of 0.211 was 99.0 mm and $K = 1.10\ yr^{-1}$ (Fig. 6.2). The modes in the length-frequency data were separated for each month using Bhattacharya's method and through modal progression analysis and the means were grouped for each cohort. The monthly modes were connected and saved as growth increment file. As observed in many off-shore shrimp species, in the case of *S. choprai* also, the size range obtained from the commercial fishery was comparatively narrow (overall size range is 46-95 mm with majority in 71-80 mm) and only few cohorts could be traced beyond two modes even after smoothing the data with 'gear selection' parameters (Table 6.5). The growth parameters estimated using the Gulland and Holt plot were $L_\infty = 100.8$ mm and $K = 1.36\ yr^{-1}$ (Fig. 6.3). The values of L_∞ and K obtained by ELEFAN I plot were taken to represent the growth in male *S. choprai.*

By using Gulland's formula (Gulland, 1969), t_0 for male is calculated as -0.050. The input values for the formula was obtained from the values of length obtained for different age in months from the graph plotted by using ELEFAN I. The t_0 was also calculated by Pauly's equation (Pauly, 1979) to find the applicability of this empirical formula in shrimps. From this equation, the value of t_0 for male was calculated as -0.045. As generally used in the case of shrimps, in the present study also the t_0 obtained from Gulland's formula was used for further analysis.

The life span estimated for male was about 2 ½ years. By VBGF, it was estimated that male of *S. choprai* attains a length of 68 mm at the end of first year and 89 mm at the end of second year.

4.6.1.2.2. Female

The data used for fitting regression for estimation of growth parameters using Powell-Wetherall method are shown in Table 6.6. The L_∞ obtained by Powell-Wetherall method was 117.9 mm and *Z/K*, 4.89 (Fig. 6.4). Estimated values by ELEFAN I method were L_∞ = 120.0 mm and K = 1.18yr^{-1} (Fig. 6.5) with an R_n value of 0.206. Table 6.7 shows the mean values obtained in different months employing Bhattacharya method. The monthly mean values of cohorts were connected and saved as growth increment data files. In this case, comparatively more numbers of cohorts could be traced beyond two modes compared to those of males (Table 6.7). By Gulland and Holt plot, L_∞ and K were calculated as 119.7 mm and 1.18 yr^{-1} respectively (Fig. 6.6), which were similar to the values obtained by ELEFAN I. The growth parameters obtained through ELEFAN I method were taken to represent the growth in female *S. choprai.* By using Gulland's formula, t_0 for female was calculated as -0.038 and by Pauly's empirical formula t_0 was calculated as -0.039. As generally used in the case of shrimps, in the present study also the t_0 obtained from Gulland's formula was used for further analysis.

It was estimated that females of the species attain a length of 85 mm at the end of first year, 109 mm at the end of second year and live for about 2 ½ years.

4.6.1.2.3. Sexes pooled

The estimated growth parameters using both male and female samples (pooled) of *S. choprai* using Powell-Wetherall method are shown in Table 6.8. The calculated value of L_∞ was 118.1 mm and *Z/K*, 4.95 (Fig. 6.7). Using the different options in ELEFAN I the best (R_n = 0.182) value of VBGF parameters obtained were L_∞ = 120.0 and K = 1.18 (Fig. 6.8). The monthly mean values of cohorts were connected and saved as growth increment data files. In this case also difficulties were faced in tracing the growth of cohorts beyond two modes even after smoothing the data with 'gear selection' parameters (Table 6.9). The growth parameters, L_∞ and K estimated using the Gulland and Holt plot were 121.1 mm and 1.24 yr^{-1} respectively (Fig. 6.9). The L_∞ and K values obtained by ELEFAN I method were considered for stock assessment of *S. choprai* along the Karnataka coast (stock assessment part). The t_0 was calculated as -0.038 and -0.039 using Gulland's formula and Pauly's empirical equation respectively.

The growth parameters derived from the length-frequency data of *S. choprai* using FiSAT software are given in Table 6. 10. The data used for t_0 estimation in males and females are given in the Tables 6.11 and 6.12. The selected growth parameters are given in Table 6.13. von Bertalanffy growth curves drawn with the selected growth parameters are shown in Fig. 6.10.

Longhurst and Pauly (1987) derived index of growth performance, Φ' which combines L_∞ and K to give an expression of growth potential of the species. This value is important for comparing growth performance of shrimps of the same species or between the species of the same genus, which can be estimated by the formula,

$$\Phi' = \log_{10} K + 2 \log_{10} L_\infty$$

In shrimp growth studies, some authors used this formula by taking annual K and L_∞ (total length) as in the case of fishes, but Dall *et al.* (1990) suggested weekly value for K instead of annual growth coefficient and L_∞ in terms of carapace length instead of total length for deriving growth performance in shrimps. Since this is a pioneering work in *S. choprai*, for future reference Φ' values obtained from both the methods are given here. By using first method, the Φ' values were 4.03, 4.23 and 4.23 for males, females and both sexes pooled respectively, whereas by second method the values obtained were 1.23, 1.49 and 1.49 respectively.

4.6.1.3. Recruitment pattern

With the growth parameters L_∞ = 120 mm, K = 1.18 yr^{-1} and t_0 = -0.038, the recruitment pattern obtained by FiSAT is given in Fig. 6.11. Recruitment to the fishery takes place throughout the year. Nevertheless, two pulses were seen in the recruitment pattern, the first one corresponds to May (19.27%) and the second one to February (14.10%).

4.6.2. DISCUSSION

Age and growth study on *S. choprai* is not reported from any part of the world. However, the size composition of the species from the Indian waters was reported by various workers. Kurien and Sebastain (1976) recorded a size of 130 mm for a female and is the largest size reported in this species so far. Aravindakshan and Karbhari (1994) reported that males of the species collected from Bombay waters were always smaller than 100 mm in total length and in females the largest size recorded was 125 mm with the major catch constituted by size range below 100 mm. Tirmizi and Bashir (1973) noted only smaller size groups of 70-90 mm, occurring off the coast of Pakistan. During the present study the largest male and female specimens recorded were having a length of 94 and 114 mm respectively with the most of the fishery constituted by the size groups of 71 to 95 mm. During 2003 the mean size of the males and females were 74.7 mm and 86.7 mm and were reduced to 72.0 mm and 82.7 mm respectively in 2004. It was also seen that total landings of the species also were reduced substantially from 2003 to 2004 (fishery part). These reductions indicate that the stock is being subjected to heavy fishing pressure.

The studies on age and growth of penaeid shrimps in Indian waters were mainly based on length-frequency method. Out of this many workers used "modal progression analysis" by connecting the modes of length-frequency by smooth lines on graph paper (Ramamurthy *et al.*, 1975; Thomas, 1975; 1978; Lalithadevi, 1986; 1987 and Sarada, 2002). Others have used computer aided LFSA and EFEFAN routines for the estimation of growth in penaeid shrimps (Suseelan and Rajan, 1989; Rao and Krishnamoorthi, 1990; Nandakumar and Srinath, 1999 and Dineshbabu, 2005). Mathews *et al.*, (1987) compared the growth parameters of penaeids obtained by ELEFAN method with that of traditional length-frequency method and concluded that ELEFAN produced the most reliable estimates of growth for three most important shrimp species of Kuwait waters.

In the present study, the growth parameters were initially estimated by Powell-Wetherall plot, followed by ELEFAN I and modal progression analysis using Gulland and Holt plot. Apart from the K values obtained for males by ELEFAN I and Gulland and Holt plot (1.10 and 1.36), all the other values were almost identical. Since, the number of modes available for the modal progression studies for males was few and the subjectivity involved in identifying modes in Gulland and Holt method were high due to multiple spawning (Dall *et al.*, 1990), the values obtained by ELEFAN I were used to describe the growth of *S. choprai* from Karnataka waters and the same were considered for stock assessment studies. ELEFAN I method is described as more reliable and highly recommended objective method for studying single species dynamics in a multi species context (Pauly, 1980a, 1982a). The L_∞

values derived from the present study, 99.0 mm for males and 120.0 mm for females, were found to be reasonable, not far away from the maximum length obtained in the fishery (94 mm for male and 114 mm for females).

As per the von Bertalanffy's growth formula, males and females attain 94 mm and 114 mm in about 30-32 months. It was estimated that males and females of *S. choprai* attained a length of 68 and 85 mm at the end of first year, 89 and 109 mm at the end of second year respectively. Since the size at first maturity has been estimated at 55 and 66 mm respectively, the shrimp was able to mature and spawn before they complete one year of its life (in 8 to 9 months).

The month-wise size frequency distribution of males showed that maximum numbers were seen in 71 to 80 mm during 2003- 2004. It can be assumed that these shrimps belong to 1+ year class. In the case of females, maximum number was caught in the length class of 81 to 95 mm and the fishery of females was assumed to be constituted by 1+ year class.

Several workers have studied the growth of species belonging to *Solenocera* genus. Kunju (1968) and Sukumaran (1978) conducted age and growth studies on *S. crassicornis* from Bombay waters using modal progression analysis. Kunju (1968) was of the opinion that females of *S. crassicornis* have a faster growth rate than males, whereas Sukumaran (1978) reported that males have a faster growth rate than females. During the present study females were found to grow faster than males.

Growth studies of *S. melantho* was carried out by Ohtomi and Irieda (1997) at Kagoshima Bay of Japan. The growth parameters estimated in the study were L_∞ = 33.09 mm (carapace length) and K = 0.857 yr^{-1} for males and L_∞ = 45.76 mm (CL) and K = 0.777 yr^{-1} for females. The longevity of males and females was considered as around 37 months. Gueguen (1998) carried out growth studies in *S. acuminate* and estimated that the species have a life span of two years and females attain sexual maturity before reaching one year. During the present study the life span of *S. choprai* was estimated as 2½ years and all shrimps were found to mature before reaching one year.

Index of growth performance, Φ' which combines K and L_∞ was used to give an expression of the growth potential of the species. Dall *et al.* (1990), while studying the index of growth coefficient in several penaeid shrimps found that the index showed considerably low variability than original K and L_∞ within a genus, with a mean of 1.91 $\pm$ 0.67 (n = 76) for *Penaeus,* 1.62 $\pm$ 0.27 (n = 14) for larger *Metapenaeus* and 1.32 $\pm$ 0.29 (n = 13) in smaller *Metapenaeus.* He also stated that sufficient data was not available to derive the index in other genera. In his studies he used K as weekly growth and L_∞ in terms of carapace length. By taking these parameters from the present study the Φ' were estimated for males and females as 1.23, and 1.49 respectively. From the values estimated for K and L_∞ in *S. melantho* (Ohtomi and Irieda, 1997) it can be calculated that in males and females Φ' were 1.26 and 1.50

respectively which were almost identical to those obtained in the present study.

In the present study it was estimated that recruitment to the fishery takes place throughout the year with two pulses in the recruitment pattern, *viz.*, a well defined one during May and another extended one from December to February. By analysing the length range in the commercial fishery of *S. choprai*, it can be assumed that recruitment takes place at a size of 40-50 mm when they are 5 to 6 months of age. Well defined peak in recruitment indicated in May corresponds to the spawning occurred during November in the previous year and the second extended peak (December-February) correspond to the extended spawning season starting from pre-monsoon period and extending throughout monsoon season. It can also be assumed that spawning occurs throughout the monsoon season, for which catch details were not available due to ban for trawling during monsoon. However, the good percentage of matured females caught during August, when fishery was resumed after the monsoon justifies this assumption.

Table 6.1. Size-distribution and mean size of *S. choprai* (males) landed at Mangalore and Malpe fisheries harbours.

2003

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
48	0	0	0	0	0	0	0	1	0	0	0	1
53	0	1	0	0	0	1	0	0	0	0	0	2
58	2	0	0	6	9	0	0	4	0	3	2	26
63	36	8	0	51	57	8	0	6	2	11	36	215
68	46	2	2	56	47	2	2	25	14	26	46	268
73	49	8	14	10	22	8	14	93	47	62	49	376
78	58	10	6	3	3	10	6	139	56	64	58	413
83	27	0	0	1	3	0	0	72	39	32	27	201
88	2	0	0	1	0	0	0	4	9	7	2	25
93	0	0	0	0	0	0	0	0	0	2	0	2
Mean size (mm)	**70.8**	**70.9**	**73.9**	**68.6**	**66.2**	**70.4**	**74.0**	**76.7**	**76.7**	**73.7**	**74.1**	**74.7**

2004

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
48	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	1	0	0	0	0	0	0	0	0	1
58	0	0	4	11	4	8	0	0	4	0	0	31
63	2	1	17	46	45	26	10	22	13	1	11	194
68	12	13	27	76	82	28	14	35	25	17	43	372
73	29	22	33	31	61	23	21	45	92	73	67	497
78	29	4	4	7	9	6	6	13	32	67	25	202
83	24	0	2	4	9	0	2	2	50	17	10	120
88	8	0	0	0	5	0	1	0	25	1	3	43
93	2	0	0	0	0	0	0	0	1	0	0	3
Mean size (mm)	**78.8**	**71.6**	**70.4**	**67.6**	**69.8**	**67.6**	**71.1**	**77.3**	**75.5**	**75.3**	**70.0**	**72.0**

Table 6.2. Size distribution and mean size of *S. choprai* (females) landed at Mangalore and Malpe fisheries harbours.

2003

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
53	0	0	0	0	0	0	0	1	0	0	0	1
58	0	0	0	0	6	0	6	0	0	0	0	12
63	8	0	0	16	5	0	51	5	2	1	8	96
68	17	0	0	37	25	2	56	8	1	3	17	166
73	33	2	0	54	46	14	10	21	9	11	33	233
78	37	6	1	26	37	6	3	38	17	13	37	221
83	52	19	8	19	15	0	1	70	31	38	52	305
88	37	18	12	12	4	0	1	79	49	45	37	294
93	38	14	15	7	1	0	0	83	58	57	38	311
98	16	10	4	0	1	0	0	23	22	19	16	111
103	6	4	2	0	0	0	0	2	5	5	6	30
108	0	0	0	0	0	0	0	0	1	0	0	1
Mean size (mm)	**87.5**	**78.6**	**90.3**	**75.2**	**73.9**	**73.4**	**85.7**	**87.6**	**87.8**	**87.6**	**84.9**	**86.3**

2004

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
53	0	0	0	0	0	0	0	0	0	0	0	0
58	0	12	3	6	0	2	0	0	3	0	0	26
63	1	19	17	10	2	3	1	1	2	1	0	57
68	1	7	14	18	8	5	2	1	4	2	1	63
73	1	4	18	36	28	13	7	14	13	4	6	144
78	5	21	16	33	22	25	22	26	19	11	19	219
83	5	24	12	29	30	14	21	47	57	14	45	298
88	13	11	8	20	17	14	12	22	39	25	33	214
93	25	6	19	3	4	6	3	7	42	12	37	164
98	19	4	5	1	4	1	2	2	19	5	14	76
103	8	0	1	0	0	0	0	0	8	1	2	20
108	5	0	0	0	0	0	0	0	0	0	0	5
Mean size (mm)	**92.8**	**76.0**	**78.9**	**74.8**	**81.3**	**79.4**	**81.4**	**89.9**	**86.6**	**85.5**	**89.0**	**82.7**

Table 6.3. Size-distribution of *S. choprai* (sex pooled) landed at Mangalore and Malpe fisheries harbours.

2003

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
48	0	0	0	0	0	0	0	1	0	0	0	1
53	0	1	0	0	0	1	0	1	0	0	0	3
58	2	0	0	6	15	0	6	4	0	3	2	38
63	44	8	0	67	62	8	51	11	4	12	44	311
68	63	2	2	93	72	4	58	33	15	29	63	434
73	82	10	14	64	68	22	24	114	56	73	82	609
78	95	16	7	29	40	16	9	177	73	77	95	634
83	79	19	8	20	18	0	1	142	70	70	79	506
88	39	18	12	13	4	0	1	83	58	52	39	319
93	38	14	15	7	1	0	0	83	58	59	38	313
98	16	10	4	0	1	0	0	23	22	19	16	111
103	6	4	2	0	0	0	0	2	5	5	6	30
108	0	0	0	0	0	0	0	0	1	0	0	1

2004

Mid-point (mm)	January	February	March	April	May	June	August	September	October	November	December	Total
48	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	1	0	0	0	0	0	0	0	0	1
58	0	12	7	17	4	10	0	0	7	0	0	57
63	3	20	34	56	47	29	11	23	15	2	11	251
68	13	20	41	94	90	33	16	36	29	19	44	435
73	30	26	51	67	89	36	28	59	105	77	73	641
78	34	25	20	40	31	31	28	39	51	78	44	421
83	29	24	14	33	39	14	23	49	107	31	55	418
88	21	11	8	20	22	14	13	22	64	26	36	257
93	27	6	19	3	4	6	3	7	43	12	37	167
98	19	4	5	1	4	1	2	2	19	5	14	76
103	8	0	1	0	0	0	0	0	8	1	2	20
108	5	0	0	0	0	0	0	0	0	0	0	5

Table 6.4. Data for estimation of L_∞ and Z/K for males of *S. choprai* using Powell-Wetherall plot.

L (mean)-L' (mm)	L'	N (cumulative)	
27.717	45.50	185254	
22.736	50.50	185110	
17.781	55.50	184705	
13.124	60.50	180645	
9.352	65.50	161930	
6.485	70.50	123487	
4.505	75.50	70251	***
3.279	80.50	24368	
2.875	85.50	3532	
2.500	90.50	265	
*** regression line is fitted from this point			
$Y = 19.97 + (-0.205) * X$, r = -0.973			
Estimate of $L_\infty = 97.3$ mm			
Estimate of $Z/K = 3.871$			

Table 6.5. Results of the Bhattacharya analysis carried out for males of *S. choprai.*

Observation	Date	Mean length (mm)	
		1	2
1	15/1/03	69.78	
2	15/2/03	60.49	75.55
3	15/3/03	73.98	
4	15/4/03	68.51	
5	15/5/03	66.62	
6	15/6/03	70.5	
7	15/8/03	65.5	76.37
8	15/9/03	76.23	
9	15/10/03	76.86	
10	15/11/03	72.19	
11	15/12/03	73.23	
12	15/1/04	76.37	
13	15/2/04	71.55	
14	15/3/04	71.75	
15	15/4/04	67.37	
16	15/5/04	69.76	
17	15/6/04	67.58	
18	15/8/04	71.69	
19	15/9/04	76.33	
20	15/10/04	74.69	
21	15/11/04	75.5	
22	15/12/04	69.95	

Table 6.6. Data for estimation of L_∞ and Z/K for females of *S. choprai* using Powell-Wetherall plot.

L (mean)-L' (mm)	L'	N (cumulative)	
38.666	45.50	189891	
33.683	50.50	189800	
28.725	55.50	189546	
23.982	60.50	187706	
19.594	65.50	182506	
15.634	70.50	172009	
12.431	75.50	151343	
9.227	80.50	121343	
6.821	85.50	98496	
4.667	90.50	55770	***
3.704	95.50	19479	
3.100	100.50	4188	
2.500	105.50	503	
*** regression line is fitted from this point			
$Y = 20.02 + (-0.170) * X$, r = -0.991			
Estimate of L_∞ = 117.9mm			
Estimate of Z/K = 4.889			

Table 6. 7. Results of the Bhattacharya analysis carried out for females of *S. choprai.*

Observation	Date	Mean length (mm)		
		1	2	3
1	15/1/03	45.59	75.87	88.01
2	15/2/03	77.51		
3	15/3/03	89.66		
4	15/4/03	71.66	85.36	
5	15/5/03	73.98		
6	15/6/03	69.83	75.5	
7	15/8/03	87.01		
8	15/9/03	53.83	88.76	
9	15/10/03	76.86	90.25	
10	15/11/03	76.75	91.26	
11	15/12/03	84.05		
12	15/1/04	60.49	92.3	
13	15/2/04	62.06	82	
14	15/3/04	65.01	80.75	
15	15/4/04	73.8	86.55	
16	15/5/04	74.8	83.66	
17	15/6/04	80.26		
18	15/8/04	81.01		
19	15/9/04	71.69	90.76	
20	15/10/04	88.16		
21	15/11/04	85.62		
22	15/12/04	88		

Table 6. 8. Data for estimation of L_∞ and Z/K for *S. choprai* (sexes pooled) using Powell-Wetherall plot.

L (mean)-L' (mm)	L'	N (cumulative)	
33.221	45.50	267249	
18.241	50.50	267083	
23.282	55.50	266656	
18.619	60.50	262404	
14.738	65.50	245357	
11.820	70.50	209697	
9.889	75.50	157745	
8.244	80.50	108487	
6.678	85.50	67894	
4.648	90.50	39683	***
3.707	95.50	13735	
3.080	100.50	2972	
2.500	105.50	345	
*** regression line is fitted from this point			
$Y = 19.48 + (-0.168) * X$, r = -0.993			
Estimate of L_∞=118.1 mm			
Estimate of Z/K = 4.951			

Table 6.9. Results of the Bhattacharya analysis carried out for *S. choprai* (sexes pooled).

Observation	Date	Mean length mm)		
		1	2	3
1	15/1/03	73.48	92.36	
2	15/2/03	60.5	76.4	85.5
3	15/3/03	74.18	89.25	
4	15/4/03	69.51	77.01	
5	15/5/03	70.11	80.94	
6	15/6/03	70.01	75.65	
7	15/8/03	98.55	77.41	
8	15/9/03	81.87	90.48	
9	15/10/03	78.65	93.01	
10	15/11/03	76.76	91.62	
11	15/12/03	77.19	94.66	
12	15/1/04	81.26	91.76	
13	15/2/04	65.48	79.75	
14	15/3/04	70.48	82.98	
15	15/4/04	68.08	84.58	
16	15/5/04	71.18	81.44	
17	15/6/04	71.36	85.94	
18	15/8/04	76.83		
19	15/9/04	67.41	85.05	
20	15/10/04	75.26	89.58	
21	15/11/04	76.11	85.3	
22	15/12/04	69.08	75.5	93.16

Table 6.10. Results of the length-frequency analysis using various options in the FiSAT program for males, females and sexes pooled data for *S. choprai.*

Method	Male		Female		Sexes pooled	
	L_∞	K	L_∞	K	L_∞	K
Powell-Wetherall method	97.3		117.9		118.0	
ELEFAN I	99.0	1.10	120.0	1.18	120.0	1.18
Modal progression Analysis (Gulland and Holt plot)	100.8	1.36	119.7	1.18	121.1	1.24

Table 6.11. Details showing the estimation of t_0 for *S. choprai* (males) using Gulland's formula.

Age (years)	*Lt*	L_∞- *Lt*	L_∞- *Lt*/ L_∞	Log (L_∞- *Lt*/ L_∞)
(x)	(mm)	(mm)		*(y)*
0. 5	46	53	0.5353	-0.6248
0.75	54	45	0.4545	-0.7885
1.0	68	31	0.3131	-1.1611

Table 6.12. Details showing the estimation of t_0 for *S. choprai* (females) using Gulland's formula.

Age (years)	*Lt*	L_∞- *Lt*	L_∞- *Lt*/ L_∞	Log (L_∞- *Lt*/ L_∞)
(x)	(mm)	(mm)		*(y)*
0. 5	55	65	0.5417	-0.6131
0.75	70	50	0.4167	-0.8755
1.0	83	37	0.3083	-1.1766

Table 6.13. Selected VBGF parameters for *S. choprai*

Parameters/Sex	Males	Females	Sexes pooled
L_∞ (mm)	99.0	120.0	120.0
K yr^{-1}	1.10	1.18	1.18
t_0	-0.050	-0.038	-0. 038

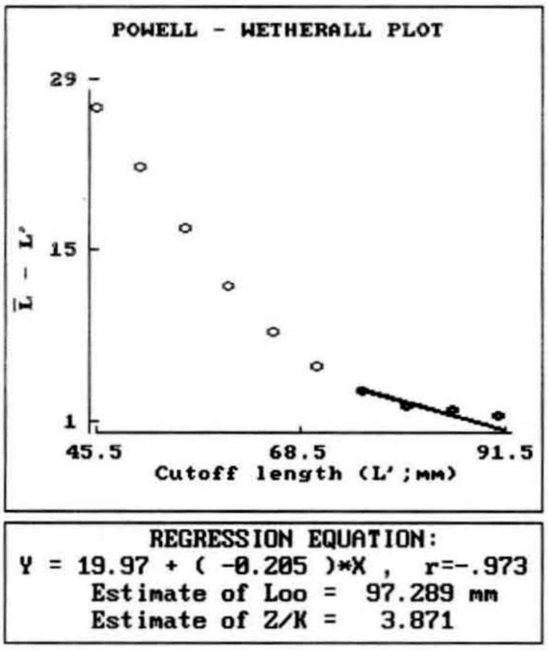


Fig. 6.1. Estimation of L_∞ and Z/K of *S. choprai* (males) using Powell-Wetherall Plot.

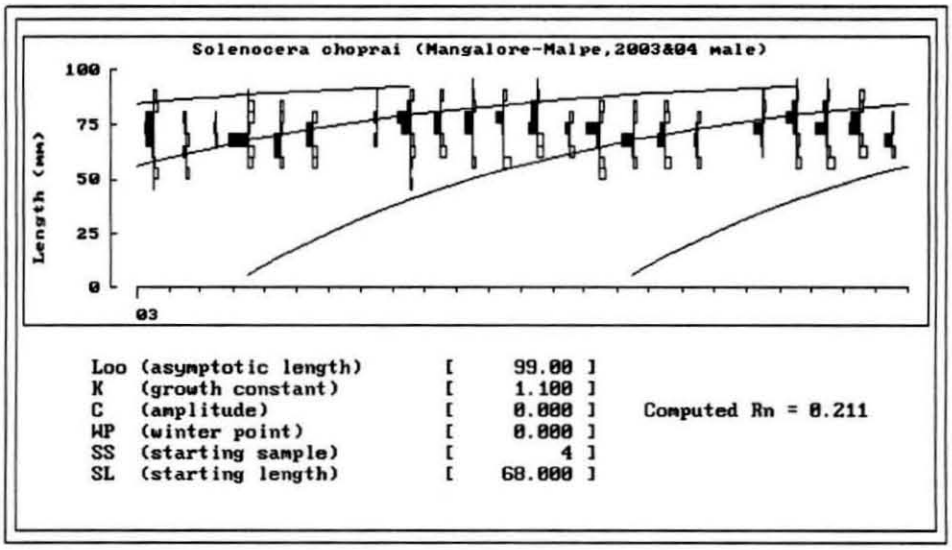
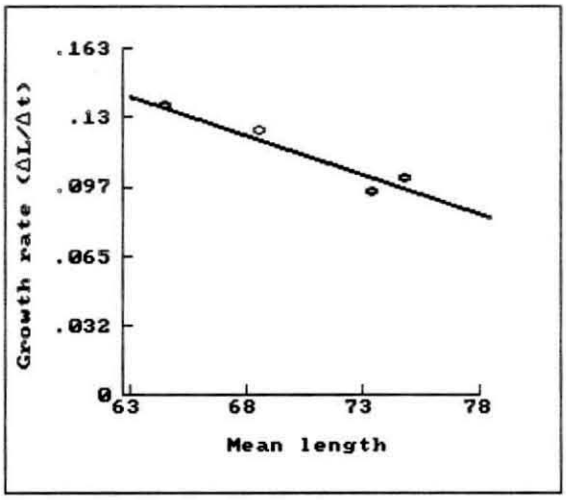
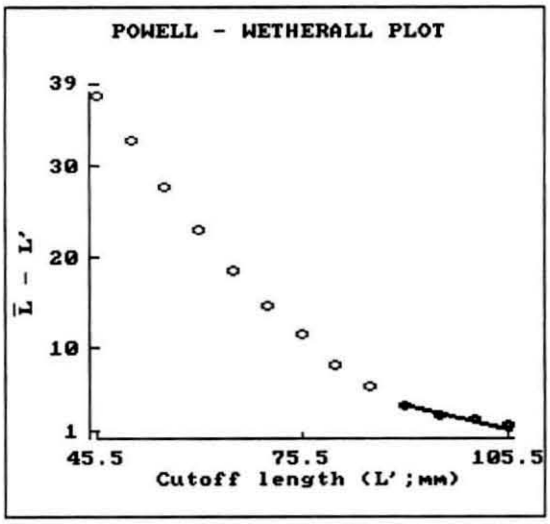


Fig. 6.2. Estimation of L_∞ of *S. choprai* (males) using ELEFAN I method.



L_∞ = 100.8 mm; K= 1.36 yr^{-1}; r^2 = 0.936

Fig. 6.3. Estimation of growth parameters using Gulland and Holt plot for *S. choprai* (males).



REGRESSION EQUATION:
Y = 20.02 + (-0.170)*X , r=-.991
Estimate of Loo = 117.876 mm
Estimate of Z/K = 4.889

Fig. 6.4. Estimation of L_∞ and *Z/K* of *S. choprai* (females) using Powell- Wetherall Plot.

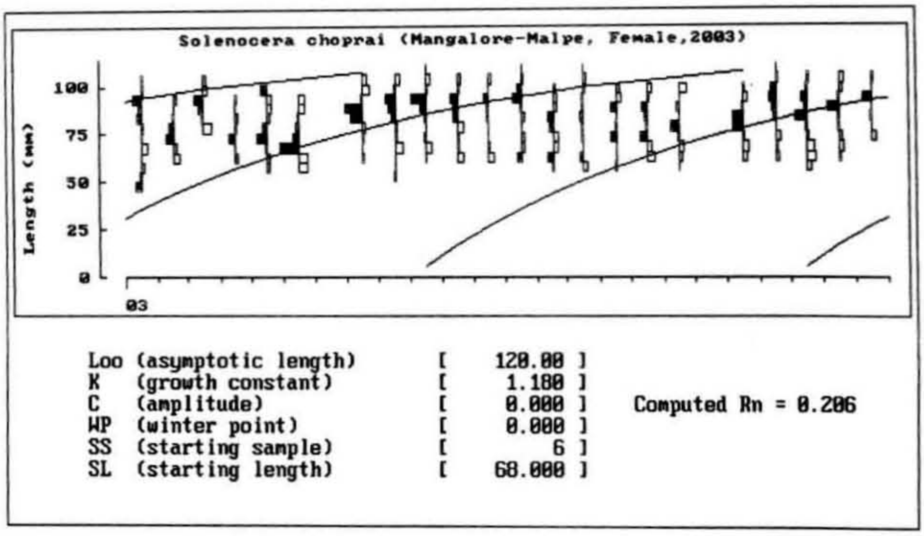
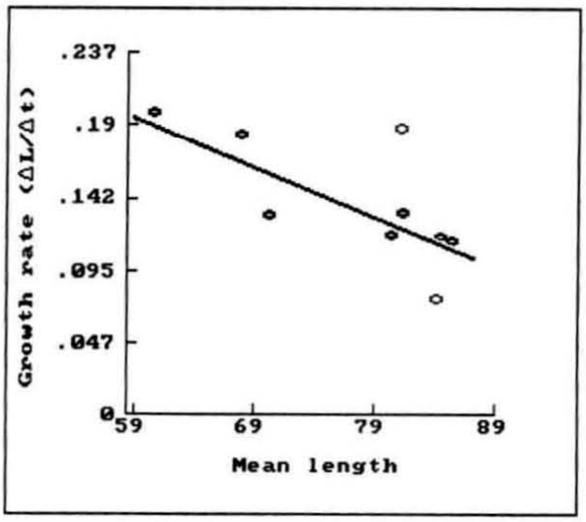


Fig. 6.5. Estimation of L_∞ of *S. choprai* (female) using ELEFAN I method.



L_∞ = 119.7 mm; K= 1.18 yr^{-1}; r^2 = 0.812

Fig. 6.6. Estimation of growth parameters using Gulland and Holt plot for *S. choprai* (females).

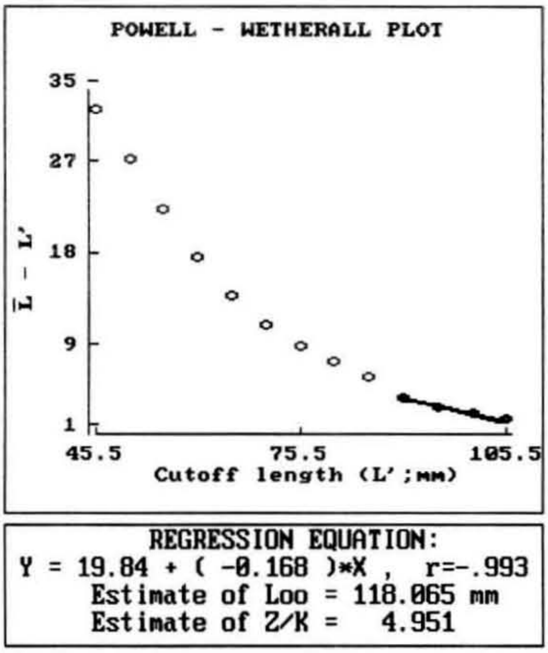


Fig. 6.7. Estimation of L_∞ and *Z/K* of *S. choprai* (sexes pooled) using Powell-Wetherall Plot.

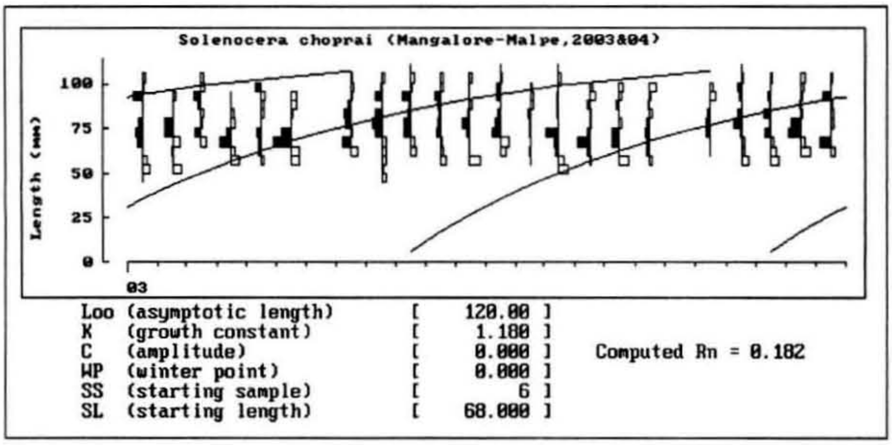
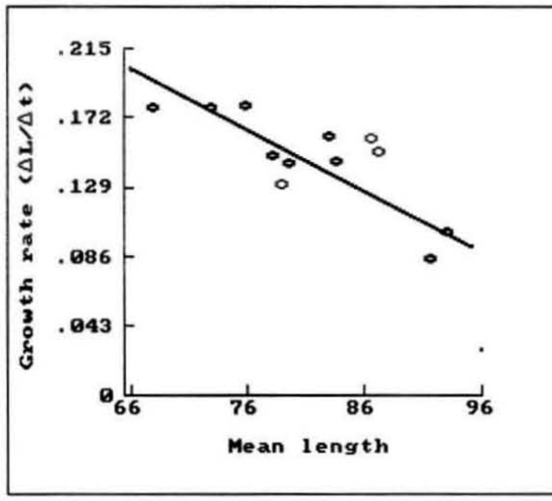


Fig. 6.8. Estimation of L_∞ of *S. choprai* (sexes pooled) using ELEFAN I method.



L_∞ = 121.1 mm; K = 1.24 yr^{-1}; r^2 = 0.871

Fig. 6.9. Estimation of growth parameters using Gulland and Holt plot for *S. choprai* (sexes pooled).

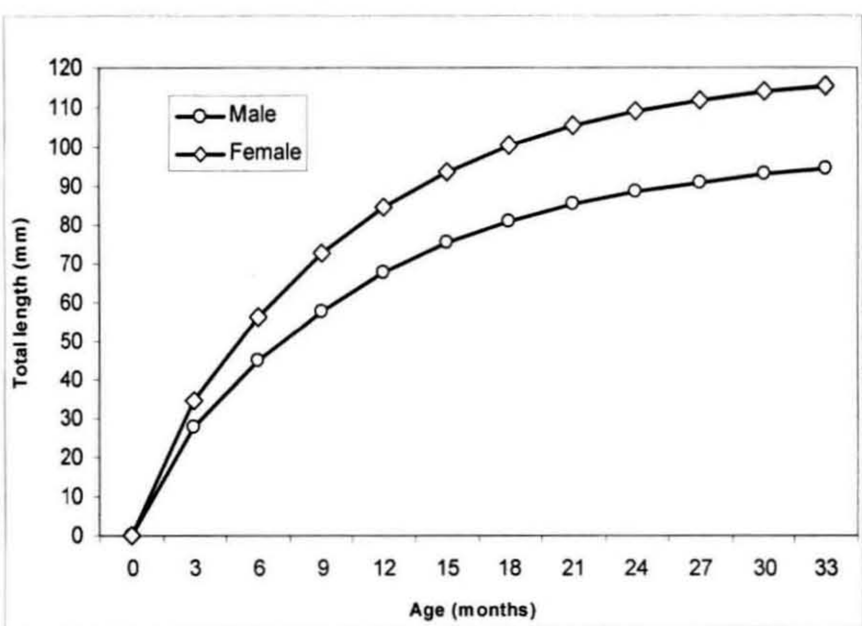


Fig. 6.10. Von Bertalanffy's growth curve of males and females of *S. choprai* with selected growth parameters.

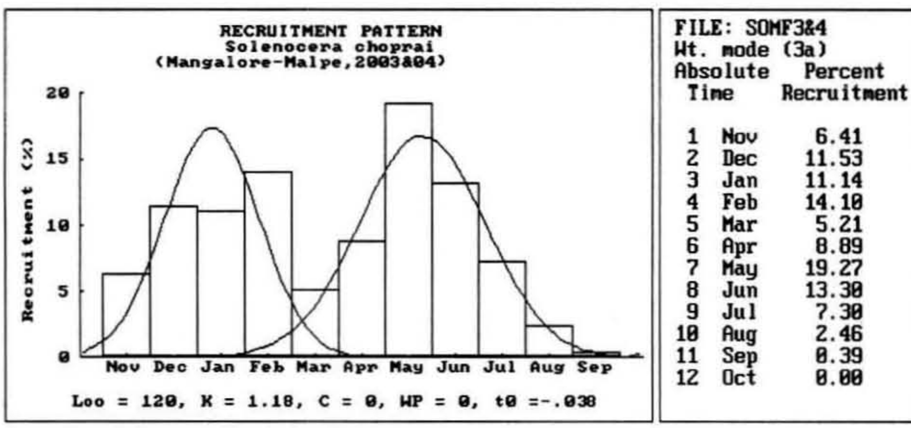


Fig. 6.11. Recruitment pattern of *S. choprai* with percentage recruitment during different months.

4.7. Stock Assessment

4. 7. STOCK ASSESSESMENT

4.7.1. RESULTS

Before starting the stock assessment study, detailed survey of the trawl landing centres of Karnataka coast was carried out and found that *S. choprai* is landed only at Mangalore-Malpe fisheries harbours. The fishing ground identified was off South Karnataka coast and from GPS readings collected from commercial trawlers it was observed that the species have a restricted distribution in patches. Off Karnataka coast the fishing ground for *S. choprai* was between 74.10^0-74.50^0 E and 12.50^0-13.20^0 N (from fishery part). By observing the position of fishing ground and the landing pattern of the species along the coast, it can be assumed that the present stock assessment holds good for entire Karnataka coast.

The catch data and the length-frequency data from Mangalore-Malpe fisheries harbours were used for the present study. The monthly estimated numbers of *S. choprai* in different size groups for the years 2003 and 2004 are given in Table 7.1.

4.7.1.1. Growth parameters

The growth parameters estimated with pooled length-frequency data of both sexes (from age and growth part) are, L_∞ = 120 mm, K = 1.18 yr^{-1} and t_0 = -0.038.

4.7.1.2. Total mortality coefficient (*Z*)

The total mortality coefficient (*Z*) was estimated separately for 2003 and 2004 by 'linearized length-converted catch curve' (Pauly, 1983) and 'cumulated catch curve' (Jones and van Zalinge, 1981). The *Z* values obtained with these were almost identical *viz.,* 5.49 and 5.53 for 2003, 4.27 and 4.26 for 2004 and 5.31 and 5.39 for the pooled data of two years. Since these values were almost identical, *Z* values obtained from the 'linearized length-converted catch curve' were used as total mortality coefficient, *Z* for further analysis. The results of the mortality estimation by 'catch curve' methods for 2003, 2004 as well as for pooled data for two years are shown in Figs. 7.1 to 7.6.

4.7.1.3. Natural mortality coefficient (*M*)

The natural mortality coefficient values estimated by different methods are shown in Table 7.2. The values were 2.48 by Pauly's empirical formula, 1.84 by Sekharan's method, 1.90 by Rikhter and Efanov method and 2.20 by Srinaths's formula. Since all these methods used here have its own scientific basis, averaging the value for *M* to get the mean is not desirable. *M* value derived from Srinath's formula was found to have minimum standard deviation from the mean and was selected to represent the natural mortality coefficient of *S. choprai* for further studies.

4.7.1.4. Probabilities of capture and length at first capture (l_c)

The results of the length-converted catch curve method were used for the estimation of probabilities of capture and l_c (Fig. 7.7). The selection values obtained by the probability of capture were L_{25} = 64.89 mm, L_{50} = 68.83 mm and L_{75}= 73.07 mm. These values were used as inputs in Thompson and Bell yield prediction analysis and relative *Y/R* of Beverton and Holt (Y'/R).

4.7.1.5. Fishing mortality coefficient (*F*)

The values of fishing mortality coefficient (*F*) estimated were 3.29 for 2003, 2.07 for 2004 and 3.11 for the two years pooled (Table 7.3).

4.7.1.6. Exploitation rate (*U*) and exploitation ratio (*E*)

The exploitation rate (*U*) was estimated at 0.60 in 2003 and 0.48 in 2004 and for the pooled data of two years was 0.58. The exploitation ratio (*E*) was 0.60 and 0.48 during 2003 and 2004 respectively and for the pooled data the exploitation ratio was 0.59 (Table 7.3).

4.7.1.7. Standing stock and MSY

Along the coast, *S. choprai* was caught only in trawl nets operated by multi-day trawlers. The yield (*Y*) of *S. choprai* obtained from Mangalore–Malpe coast by trawl was 1,445 t in 2003 and 752 t in 2004. The estimated total stock was 2, 408 t in 2003, 1, 565 t in 2004 and 1, 893 t, average for the two years pooled. The standing stock for the years 2003 and 2004 were estimated as 439 t and 362 t respectively. By Gulland's formula (Gulland, 1971), MSY of *S. choprai* for 2003-2004 was calculated as 937 t (Table 7.3). By using length-based Thompson and Bell prediction model, the MSY was estimated at 1,225 t for 2003-2004.

4.7.1.8. Virtual population analysis (VPA)

Results of the VPA using the pooled length-frequency data for the two years show that F increases to a maximum of 5.04 at 95-99 mm length. The mean numbers, the length-wise catch and the steady state biomass pertaining to each length class (Table 7.4) showed that catch constituted mainly of 70-94 mm length group and maximum catch (191.88 t) was obtained in the size class of 80-84 mm. The yield increased from 0.70 t in the size class 45-49 mm to the maximum of 191.88 t in the size class 80-84 mm and gradually reduced to 4.73 t in 105 mm + size class (Fig. 7.8).

4.7.1.9. Length-based Thompson and Bell model

The size-wise average market price of *S. choprai* used for estimation of maximum sustainable economic yield (MEY) in Thompson & Bell routine is given in Table 7.5. The price ranged from Rs. 2 per kg for 45-54 mm size to a maximum of Rs. 40 per kg for shrimps of length 105 mm and above. The analysis showed that MEY of Rs.23.20 million is obtained by the present level of fishing (Table 7.5). Average yield of *S. choprai* for the period 2003-2004 calculated from length-based Thompson and Bell prediction model was 1,070 t and the maximum sustainable yield (MSY) calculated from this is

1,225 t. As per Thompson and Bell prediction model (Fig. 7.9), any subsequent addition of effort from the present level (ie., 100 to 120%, 120 to 140% and 140 to 160%), will result only comparatively very low additional yields (3.46%, 2.44% and 1.76% respectively) (Table 7.5). In the light of the results obtained from Thompson and Bell yield analysis, it appears that there is no scope for increasing the fishing effort to result higher economic yield and that the fishery is already operating near the biologically optimum level. By analysing shrimp landings data it was observed that average annual fishing effort expended by multi-day trawlers from Mangalore-Malpe fisheries harbours during 2003-2004 was 18.16 million fishing hours resulting in an average annual landing of 1,098 t.

4.7.1.10. The relative Y/R model (Y'/R)

The parameters used as inputs for Beverton and Holt yield per recruit analysis and the different Y/R values obtained against respective *F* values for *S. choprai* are presented in Table 7.6. Fig. 7.10 shows that the present exploitation rate, (*E)* 0.59 is little below the optimum exploitation rate (E_{max} = 0.646). The $E_{-0.1}$ was estimated as 0.6159 and $E_{-0.5}$ as 0.3672. It was seen that the increase in effort by 100% from the present effort (Table 7.7) enhance Y/R by only 10.4% and further increase in effort will lead to lesser percentage of increase in Y/R. Thus, it was observed that there shall not be any significant improvement in the yield with the increase in fishing mortality (increase in fishing effort).

The yield isopleths were used to find out the combination of fishing effort and age at which the cohorts become vulnerable to fishing (age at first capture). The yield isopleth for *S. choprai* (Fig. 7.11) revealed that the increase in the current level of age at capture (0.75 years) as well as enhancement of present fishing effort (*F*) will not result in significant improvement in the yield of *S. choprai* along Mangalore-Malpe coast. To understand the impact of increasing the mesh size on yield and biomass, Y/R and B/R of *S. choprai* was estimated with present T_c (0.75 years) and a higher T_c (1.0 year). Y/R and B/R plotted against various fishing efforts (Fig. 7.12) showed that in all effort levels the Y/R was high with present T_c and biomass also did not show any significant improvement by using higher T_c. Thus, yield per recruitment analysis indicated that the present pattern of exploitation of *S. choprai* along this coast seems to be nearer to optimum yield.

4.7.2. DISCUSSION

Progress on studies on shrimp population dynamics in tropical waters has been slow even though great strides have been made in temperate region since 19th century. The main hindrance in the study of population dynamics of tropical shrimps are the well known problems such as difficulty in the direct determination of age and also the existence of large number of species supporting the fishery. The stock assessment investigations from tropical waters gained momentum in the eighties due to the introduction of length-based methods and models and also by the development of suitable computer softwares like ELEFAN, LFSA and FiSAT. No attempt has been made so far to estimate the mortality parameters and stock of *S. choprai* from the Indian waters or any part of the world and the present study is the first of its kind. In the present study, growth and mortality parameters were estimated using the routines available in FiSAT.

For estimating natural mortality coefficient (*M*), several simple methods are available and the best and easy method is regressing *Z* against effort (Sparre and Venema, 1992). However, in the tropical multi-species system, apportioning of effort for a single species is difficult. Hence, this method could not be attempted in this study. Moreover, as natural mortality is influenced by several biological and environmental factors, it is difficult to get an accurate estimate (Pauly, 1980). Further, it is also related to other growth parameters like L_∞ (Sparre *et al.,* 1989) and maturity (Rikhter and Efanov, 1976). The empirical equation of Pauly (1980) and Srinath (1990) and methods described by Sekharan (1974) and Rikhter and Efanov (1976) were used to derive natural mortality in the present study. The *M* estimates by the above four methods varied from 1.84 to 2.48.

The natural mortality (*M*) is closely related to age and size, as larger species or groups generally would have less rate of predation. Since *M* is linked to longevity and the size to growth coefficient *K*, *M/K* ratio is found constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959 and Banerji, 1973). *M/K* ratio usually ranges from 1 to 2.5 (Beverton and Holt, 1959). In the present study, the *M/K* ratio obtained for *S. choprai* was 1.86. The *M/K* ratios obtained with *M* values from all the four methods (1.55 to 2.10) fall within the range. *F* was obtained from the relation $Z = M+F$. The present exploitation rate (E) = 0.59 is lower than E_{max} of 0.65.

By using Baranov's (1918) catch equation, the average total stock (*Y/U*) was calculated as 1,893 t and average standing stock (*Y/F*) as 353 t. As the estimate of MSY stands between 937 t (Gulland's formula) and 1, 225 t (Thompson and Bell model) in the present study, against the present average catch of 1,098 t, it is evident that the stock of *S. choprai* is exploited almost near to MSY level.

The relative *Y/R* showed that the E_{max} of 0.65 against the present *E* of 0.59 indicates further scope of increasing the fishing effort. However, Thompson and Bell model indicated that any subsequent addition of effort from the present level, will give comparatively very low additional yield since the present fishery stands at MEY level (Fig. 7.9). According to this model, it appears that there is no scope for increasing the fishing effort to get higher economic yield. The estimated average annual fishing effort expended by multi-day trawlers from Mangalore-Malpe fisheries harbours during 2003-2004 was 18.16 million fishing hours to get an average yield of 1,098 t per year. From stock assessment studies on *M. monoceros* from Kerala waters, Nandakumar and Srinath (1999) stated that in a multi-species fishery it is rather difficult to make harvesting strategies exclusive to particular stock. However, it is imperative and advisable to monitor from time to time the trend of the landings from the exploited stock of multi-species fishery in order to assess the status. In the present contest also since the fishing effort expended during the period of study was targeted for many other resources depending on season, it will not be possible to apportion the effort for a single species. In the light of this, close observation of the landing of *S. choprai* in the multi-stock landing and limiting the catch of the species to its MSY level can be suggested as a management measure to sustain its fishery along South Karnataka coast.

The studies conducted to understand the impact of the mesh size increase on yield and biomass (Fig. 7.12) showed that in all effort levels, the Y/R was high with present T_{c}. No significant improvement in biomass was noticed by using higher T_c, indicating that there may not have any significant improvement in yield and biomass with increase in cod-end mesh size. Therefore, it can be assumed that the present pattern of exploitation of *S. choprai* along this coast is nearer to biological optimum.

Table 7.1. Raised length-frequency data (in thousands) of *S. choprai* from trawl landings of Mangalore-Malpe fisheries harbours.

2003

Mid-point(mm)	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Oct	Nov	Dec
48	97	0	0	0		0	0	47	0	0	0
53	89	62	0	0	0	0	0	247	0	0	0
58	366	0	0	52	343	27	0	388	0	739	8
63	1095	622	0	173	1780	40	17	1449	274	2471	163
68	2123	497	44	747	1993	728	1412	2985	937	4547	286
73	2629	1678	307	527	2114	538	510	13978	3295	9479	411
78	2126	1741	154	248	1096	282	1271	19521	3991	9173	538
83	1257	870	175	179	412	148	1094	17996	3190	9132	379
88	1036	622	263	125	26	40	776	10237	2635	8353	180
93	1312	249	329	68	6	13	282	10510	3088	8664	172
98	388	0	88	0	55	0	88	5220	1009	3091	79
103	122	0	44	0	0	0	17	367	252	1009	26
108	0	0	0	0	0	0	0	0	38	0	0
113	0	0	0	0	0	0	0	0	0	0	0

2004

48	0	0	0	0	0	0	0	0	0	0	0
53	0	0	52	0	0	0	0	0	0	0	0
58	0	1022	360	2176	52	120	0	38	46	0	0
63	160	1706	1766	5818	888	354	74	324	524	32	78
68	216	1704	2284	9248	1822	404	108	588	1386	302	1020
73	2030	2214	3794	5136	2062	438	186	1340	4556	1132	490
78	2112	2130	1522	2294	956	380	188	2560	3828	1122	226
83	2030	2044	1526	1400	956	170	154	2210	6248	462	112
88	1472	938	894	1086	702	170	86	1646	3298	402	122
93	1596	512	714	138	294	74	20	1540	3140	176	192
98	1196	340	334	128	128	12	14	1136	1444	82	92
103	400	0	78	0	0	0	0	450	656	16	20
108	280	0	30	0	0	0	0	148	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0

Table 7.2. Estimates of natural mortality coefficient (M) derived from different methods.

S. No.	Method	Estimate
1	Pauly's empirical formula	**2.48**
2	Sekharan's method	**1.84**
3	Rikter and Efanove's method	**1.90**
4	Srinath's empirical formula	**2.20**

Table 7.3. Estimates of various parameters derived from the present study used for the stock estimation of *S. choprai* along Mangalore-Malpe Coast.

Year/ parameters		2003	2004	Pooled
Total mortality	*Z*	5.49	4.27	**5.31**
Natural mortality	*M*	2.20	2.20	**2.20**
Fishing mortality	*F*	3.29	2.07	**3.11**
Exploitation ratio	*E*	0.60	0.48	**0.59**
Exploitation rate	*U*	0.60	0.48	**0.58**
Yield (t)	*Y*	1445	752	**1098**
Total stock (t)	*Y/U*	2408	1565	**1893**
Standing stock (t)	*Y/F*	439	362	**353**
MSY by Gulland's formula (t)		1206	772	**937**
MSY by Thompson and Bell model (t)				**1225**
L_∞ *(cm)*				**12.00**
K *(Annual)*				**1.18**
t_0 *(year)*				**-0.038**
L_c *(cm)*				**6.90**
L_{75} *(cm)*				**7.30**
L_{max} *(cm)*				**11.40**
T_c *(year)*				**0.75**
T_{75} *(year)*				**0.83**
T_{max} *(year)*				**2.50**

Table 7.4. Details of the estimation of yield, average biomass and average value of *S. choprai* for 2003-2004 using length-based cohort analysis

Lower limit (mm)	Numbers caught (000')	Number of survivors (000')	F/Z	F	Z	Mean weight (gm)	Mean number (000')	Yield (t)	Aver. value (Rs/kg)
45	72.01	601007	0.00	0.00	2.20	1.04	32972	0.07	2
50	225.31	528397	0.00	0.01	2.21	1.84	30988	0.41	2
55	2868.59	459999	0.04	0.10	2.30	2.43	28893	6.97	5
60	9904.63	393567	0.15	0.37	2.57	3.14	26439	31.10	5
65	17690.3	325497	0.26	0.76	2.96	3.98	23404	70.34	10
70	29420.9	256319	0.41	1.51	3.71	4.95	19528	145.66	10
75	28729.3	183937	0.46	1.90	4.10	6.07	15126	174.53	20
80	26072.4	121931	0.52	2.41	4.61	7.36	10827	191.88	20
85	17554.9	72038	0.53	2.47	4.67	8.82	7111	154.76	30
90	16544.8	38839	0.66	4.23	6.43	10.45	3912	172.97	30
95	7462.54	13688	0.70	5.04	7.24	12.29	1480	91.69	30
100	1729.03	2968	0.68	4.61	6.81	14.33	375	24.77	30
105	248.19	414	0.60	3.30	5.50	19.06	75	4.73	40
Total		**2998599**					**201129**	**1069.89**	

K	1.18
L_∞	120 mm
M	2.20
$M/2K$	0.93
a	9.7E-06
b	3.06821

Table 7.5. Yield, average biomass and value derived from length-based Thompson and Bell analysis.

Effort multiplier (X)	Yield (t)	Av.biomass (t)	Value (000') (Rs.)	Addl. Yield (%)	Addl. value %
0	0	1561	0		
0.2	545	1196	14762	100.00	100.00
0.4	799	1000	20251	46.61	37.18
0.6	935	879	22370	17.02	10.46
0.8	1017	796	23099	8.77	3.26
1	1070	734	23195	5.21	0.42
1.2	1107	687	22977	3.46	0.00
1.4	1134	649	22597	2.44	0.00
1.6	1154	617	22134	1.76	0.00
1.8	1169	590	21631	1.30	0.00
2	1181	566	21114	1.03	0.00
2.2	1191	546	20597	0.85	0.00
2.4	1198	528	20090	0.59	0.00
2.6	1204	512	19600	0.50	0.00
2.8	1209	497	19129	0.42	0.00
3	1213	484	18679	0.33	0.00
3.2	1216	472	18251	0.25	0.00
3.4	1218	461	17845	0.16	0.00
3.6	1220	451	17459	0.16	0.00
3.8	1222	442	17094	0.16	0.00
4	1223	434	16747	0.08	0.00

5	1225	399	15263	**MSY**	**1225 t.**
6	1224	373	14104		

Table 7.6. Details of Beverton and Holt yield per recruit analysis of *S. choprai.*

1	2	3	4	5	6	7	8	9	10	11	12
F	Z	Z+K	Z+2K	Z+3K	1/Z	3S/Z+K	3 S^2/Z+2K	S^3/Z+3K	EXP-M(Tc-Tr)	Y/R	B/R
0	2.2	3.38	4.56	5.74	0.455	0.365	0.111	0.012	0.577	0.000	2.504
0.2	2.4	3.58	4.76	5.94	0.417	0.345	0.107	0.012	0.577	0.443	2.215
0.4	2.6	3.78	4.96	6.14	0.385	0.326	0.102	0.011	0.577	0.792	1.980
0.6	2.8	3.98	5.16	6.34	0.357	0.310	0.098	0.011	0.577	1.071	1.785
0.8	3	4.18	5.36	6.54	0.333	0.295	0.095	0.011	0.577	1.297	1.622
1	3.2	4.38	5.56	6.74	0.313	0.282	0.091	0.010	0.577	1.483	1.483
1.2	3.4	4.58	5.76	6.94	0.294	0.269	0.088	0.010	0.577	1.637	1.364
1.4	3.6	4.78	5.96	7.14	0.278	0.258	0.085	0.010	0.577	1.766	1.262
1.6	3.8	4.98	6.16	7.34	0.263	0.248	0.082	0.009	0.577	1.875	1.172
1.8	4	5.18	6.36	7.54	0.250	0.238	0.080	0.009	0.577	1.968	1.093
2	4.2	5.38	6.56	7.74	0.238	0.229	0.077	0.009	0.577	2.047	1.024
2.2	4.4	5.58	6.76	7.94	0.227	0.221	0.075	0.009	0.577	2.116	0.962
2.4	4.6	5.78	6.96	8.14	0.217	0.213	0.073	0.009	0.577	2.175	0.906
2.6	4.8	5.98	7.16	8.34	0.208	0.206	0.071	0.008	0.577	2.227	0.857
2.8	5	6.18	7.36	8.54	0.200	0.200	0.069	0.008	0.577	2.273	0.812
3	5.2	6.38	7.56	8.74	0.192	0.193	0.067	0.008	0.577	2.313	0.771
3.2	5.4	6.58	7.76	8.94	0.185	0.187	0.065	0.008	0.577	2.348	0.734
3.4	5.6	6.78	7.96	9.14	0.179	0.182	0.064	0.008	0.577	2.380	0.700
3.6	5.8	6.98	8.16	9.34	0.172	0.177	0.062	0.007	0.577	2.408	0.669
3.8	6	7.18	8.36	9.54	0.167	0.172	0.061	0.007	0.577	2.433	0.640
4	6.2	7.38	8.56	9.74	0.161	0.167	0.059	0.007	0.577	2.455	0.614

Input parameters

K (annual)	=	**1.18**
T_c	=	**0.75 yr.**
T_r	=	**0.5 yr.**
M	=	**2.2**
t_0	=	**-0.038 yr.**
W_∞	=	**23 g.**
S = exp(-K(Tc-To))	=	**0.4112**

Table 7.7. Y/R and B/R for *S. choprai* with different values of fishing effort:

Effort multiplier (X)	Yield per recruit (g) (Y/R)	Biomass per recruit (g) (B/R)	Increase in Y/R (%)
0.0	0.00000	2.50401	
0.2	0.44306	2.21532	100.0
0.4	0.79199	1.97998	78.8
0.6	1.07111	1.78519	35.2
0.8	1.29745	1.62181	21.1
1.0	1.48319	1.48319	14.3
1.2	1.63725	1.36437	10.4
1.4	1.76624	1.26160	7.9
1.6	1.87518	1.17199	6.2
1.8	1.96788	1.09327	4.9
2.0	2.04734	1.02367	4.0
2.2	2.11587	0.96176	3.3
2.4	2.17533	0.90639	2.8
2.6	2.22719	0.85661	2.4
2.8	2.27266	0.81166	2.0
3.0	2.31271	0.77090	1.8
3.2	2.34813	0.73379	1.5
3.4	2.37958	0.69988	1.3
3.6	2.40761	0.66878	1.2
3.8	2.43269	0.64018	1.0
4.0	2.45519	0.61380	0.9
Input parameters			
K	=		**1.18 per yr.**
T_c	=		**0.75 yr.**
T_r	=		**0.5 yr.**
M	=		**2.2**
t_0	=		**-0.038 yr.**
W_∞	=		**24 g.**
S = exp(-K(Tc-To))			**0.4112**

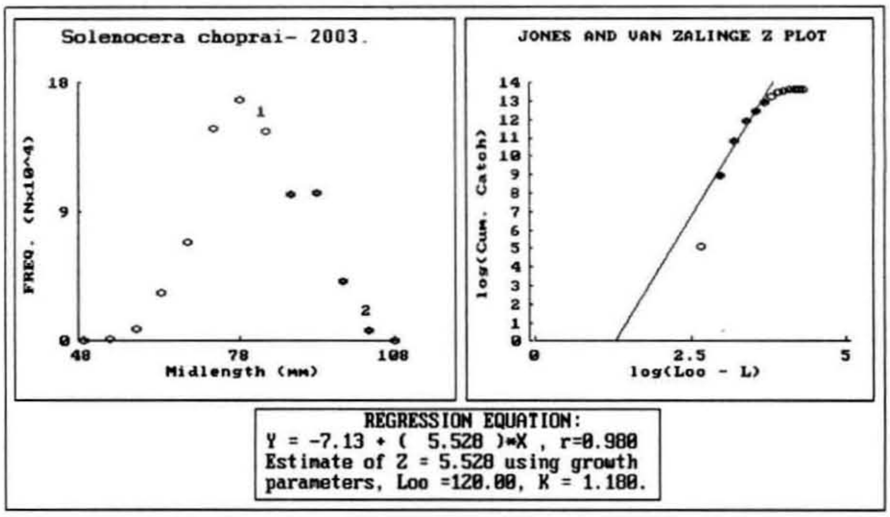


Fig. 7.1. Total mortality estimation of *S. choprai* in 2003 using Jones and Van Zalinge's cumulative catch curve method.

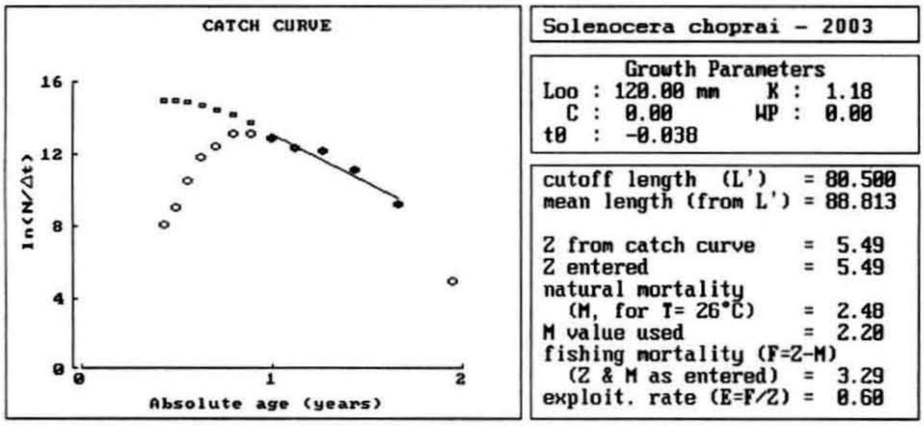


Fig. 7.2. Total mortality estimation of *S. choprai* in 2003 using Pauly's linearised length-converted catch curve method and estimation of exploitation rate of *S. choprai*.

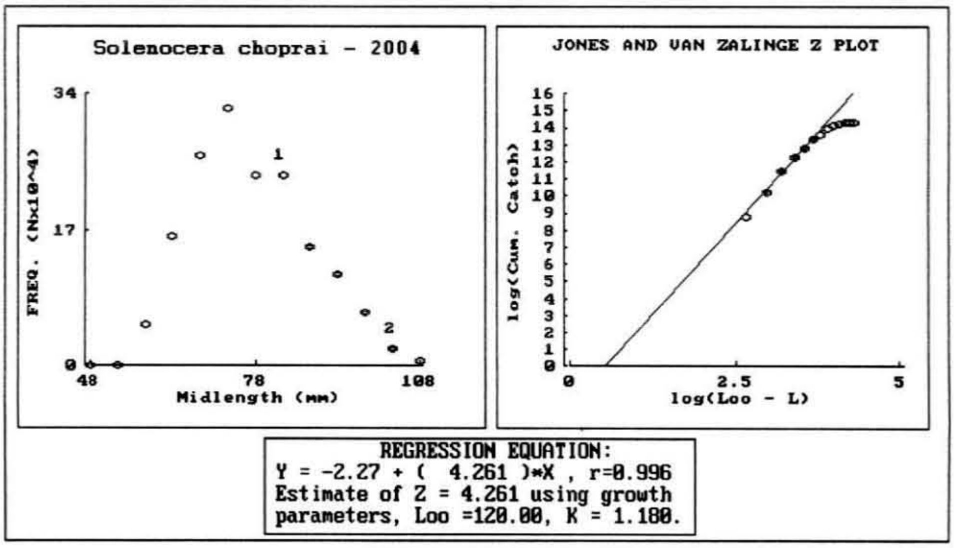


Fig. 7.3. Total mortality estimation of *S. choprai* in 2004 using Jones and Van Zalinge's cumulative catch curve method.

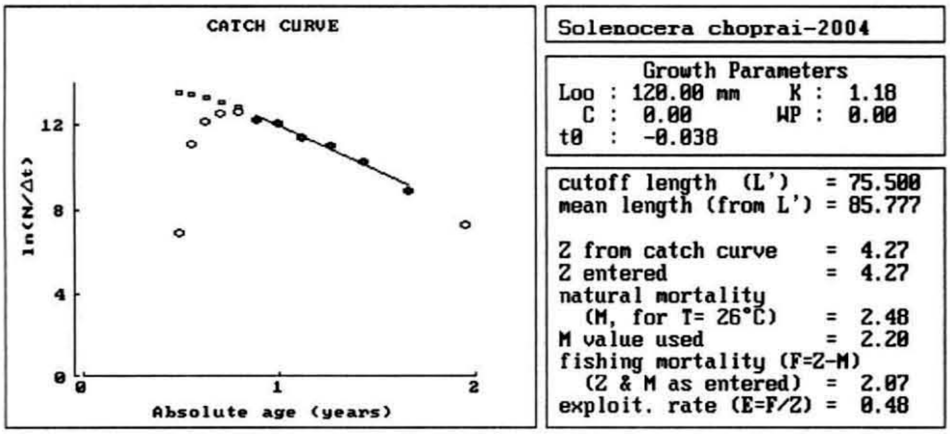


Fig. 7.4. Total mortality estimation of *S. choprai* in 2004 using Pauly's linearised length-converted catch curve method and estimation of exploitation rate of *S. choprai.*

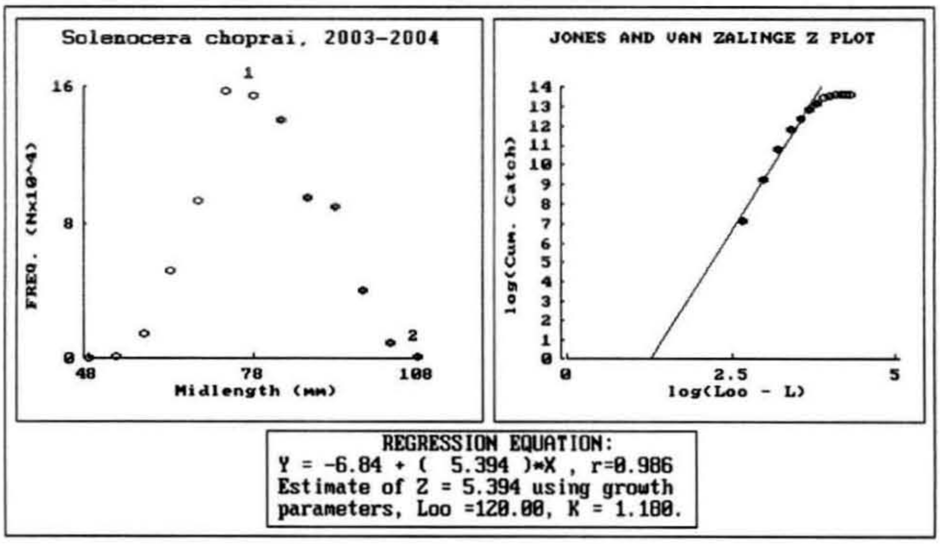


Fig. 7.5. Total mortality estimation of *S. choprai* during 2003-2004 using Jones and Van Zalinge's cumulative catch curve method.

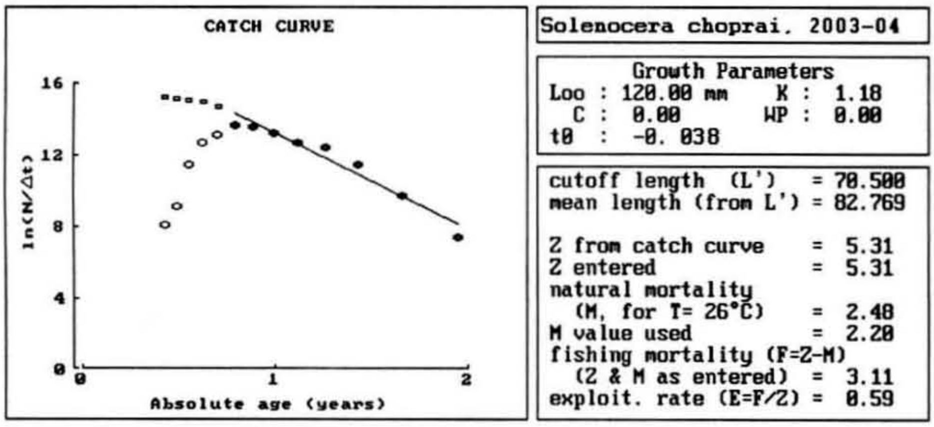


Fig. 7.6. Total mortality estimation of *S. choprai* during 2003-2004 using Pauly's linearised length-converted catch curve method and estimation of exploitation rate of *S. choprai*.

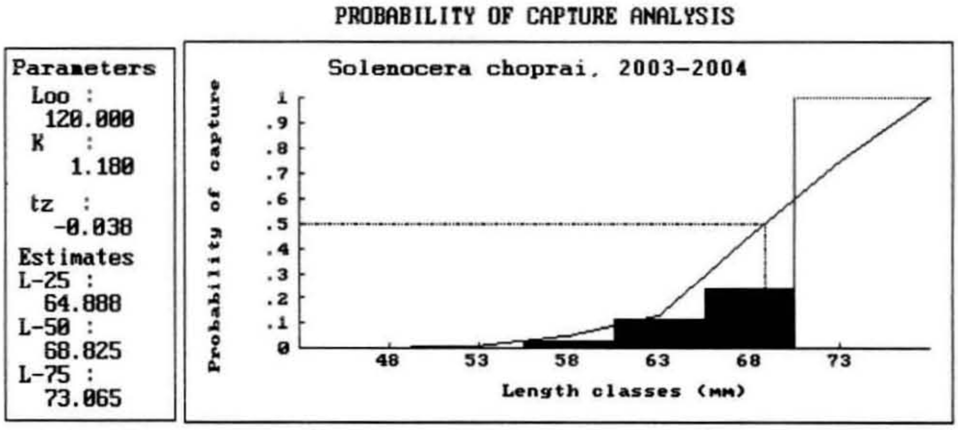


Fig.7.7. Analysis of probability of capture for *S. choprai* with length-frequency data pooled for 2003-2004.

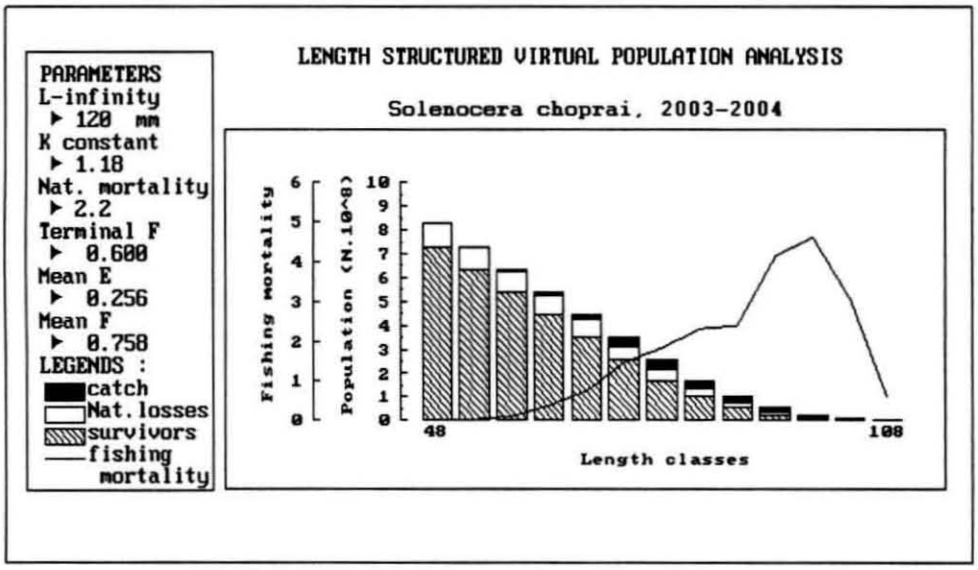


Fig. 7.8. Results of length-structured virtual population analysis of *S. choprai* with length-frequency data pooled for 2003-2004.

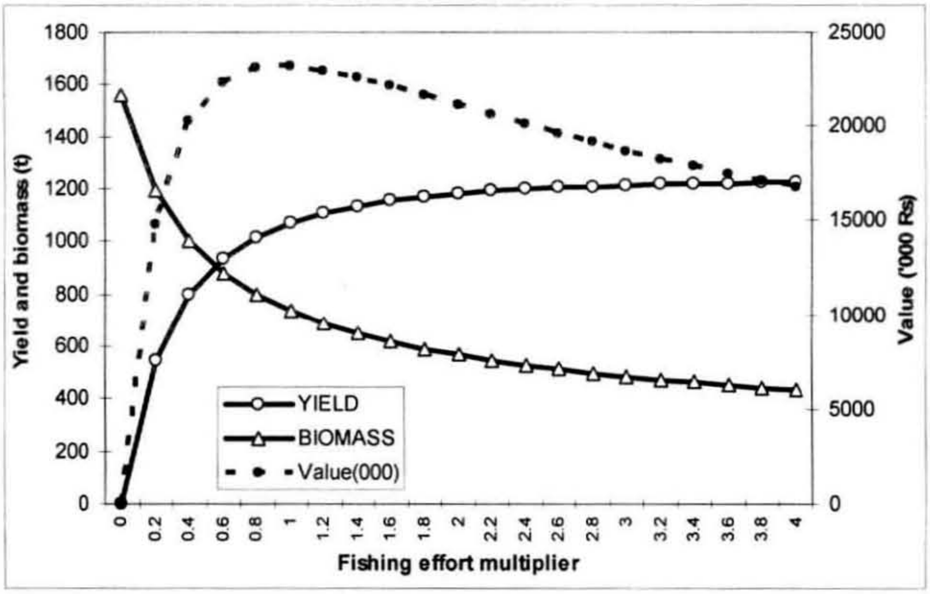


Fig. 7. 9. Results of Thompson and Bell analysis for *S. choprai* with length-frequency data pooled for 2003-2004.

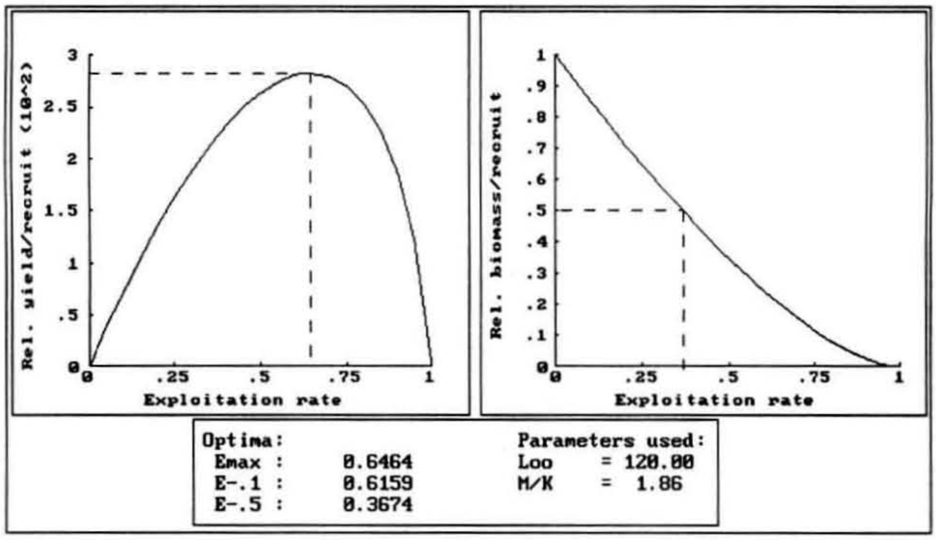


Fig. 7.10. Results of relative yield per recruit and biomass per recruit analysis for *S. choprai* indicating $E_{0.1}$ and $E_{0.5}$ (length-frequency data pooled for 2003-2004).

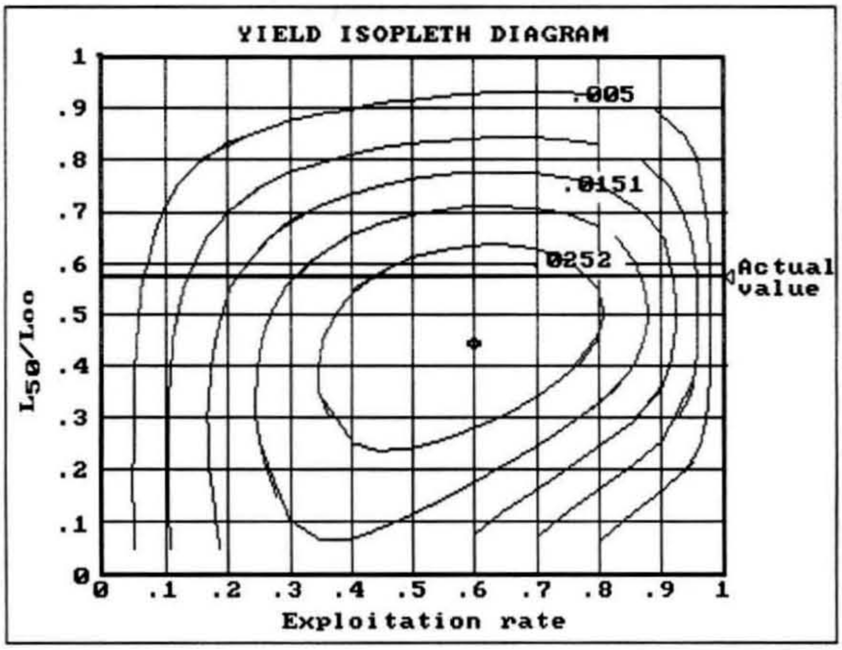


Fig. 7.11. Yield isopleth diagram indicating isolines of relative yield per recruit for *S. choprai.*

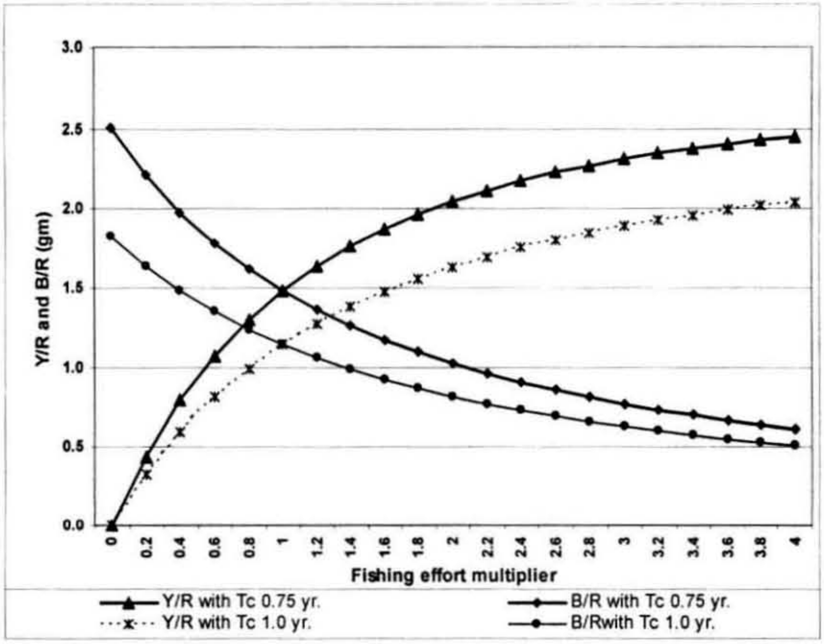


Fig. 7.12. Y/R and B/R as a function of fishing mortality in *S. choprai* with different T_c values.

Summary

- The study presents a comprehensive account on the fishery, biology and population dynamics of *Solenocera choprai* along South Karnataka coast during 2003-2004.
- Trawling for the species was invariably carried out during the night time from a depth of 60 to 100 m.
- Along Karnataka coast, *S. choprai* was landed only in two fisheries harbours, Mangalore and Malpe and 86% of the catch was landed at Mangalore.
- Unique sandy belt occurring from 50 m depth off Karnataka coast was found to harbour the species, which have a habit of burrowing in the soft sandy substratum, with the antennules of the species forming respiratory tube enabling them to respire while burrowing in the sand.
- The landing of *S. choprai* along the coast during the period of study showed a declining trend from the previous years, the landings in 2003 and 2004 were 1,445 t and 752 t respectively.
- Peak landing of the species was observed during September-October, immediately after the commencement of fishing after the cessation of southwest monsoon.
- The regression equations of length-weight relations between male and female were tested for equality showed that the values of slope and elevation differed significantly at 1% level.
- The value of exponent of total length-total weight relationship of

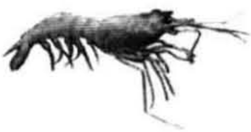
S. choprai (both sexes pooled data) was very close to 3 indicating that the growth followed an isometric pattern.

- Remains of decapod crustaceans formed the major component of the stomach content of *S. choprai*.
- Statistical analysis of variance of food content with months showed significance at 1% level.
- During the months of upwelling, 'fish remains' and detritus formed the major part of the stomach contents.
- Immature and spent females were found to feed more actively than the maturing ones.
- Size at first maturity in male was 55 mm while the same in female was 66 mm.
- The age at first maturity of *S. choprai* was worked out to be 8 months and all the shrimps were found to mature before they attain one year.
- Occurrence of mature ovaries throughout the year showed prolonged spawning season of the species. However, peak spawning season was found to be in November and another less predominant peak was observed during January-February.
- The fecundity ranged from 38,532 (80 mm *TL*) to 1,33,689 (110 mm *TL*). Ovary weight was found to be a better predictor for fecundity than total length and total body weight.
- Annual sex ratio of males and females did not vary significantly (1% level) from 1: 1.

- Smaller sized shrimps (< 80 mm) were dominated by males and bigger sized (>80mm) shrimps were dominated by females.
- The growth parameters estimated for males were $L_\infty = 99.0$ mm, $K = 1.10$ yr^{-1} and $t_0 = -0.050$ years.
- The growth parameters estimated for females were $L_\infty = 120.0$ mm, $K = 1.18$ yr^{-1} and $t_0 = -0.038$ years.
- The life span of *S. choprai* was estimated to be about 2 ½ years.
- Males and females attain a length of 68 and 85 mm respectively at the end of first year of its life and 89 and 109 mm at the end of second year of its life.
- Recruitment pattern estimated, using growth parameters showed two recruitment pulses, the one during May and the second during February.
- Natural mortality coefficient (*M*), total mortality coefficient (*Z*) and fishing mortality coefficient (*F*) during 2003-2004 were estimated as 2.2, 5.31 and 3.11 respectively.
- The exploitation ratio (*E*) for the period was 0.59. By Thompson and Bell prediction model, the annual MSY of *S. choprai* for 2003-2004 was estimated at 1,225 t against the average annual yield of 1,098 t.
- Length at first capture was estimated as 69 mm.

- Beverton and Holt yield per recruit analysis indicated that there may not be any significant improvement in yield and biomass with increase in cod-end mesh size.

- Thompson and Bell yield analysis indicates that there is no scope for increasing the fishing effort so as to get higher economic yield.
- The present pattern of exploitation of *S. choprai* along South Karnataka coast is nearer to biological optimum and limiting the catch of *S. choprai* to its MSY level can be suggested as a management measure to sustain its fishery.



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